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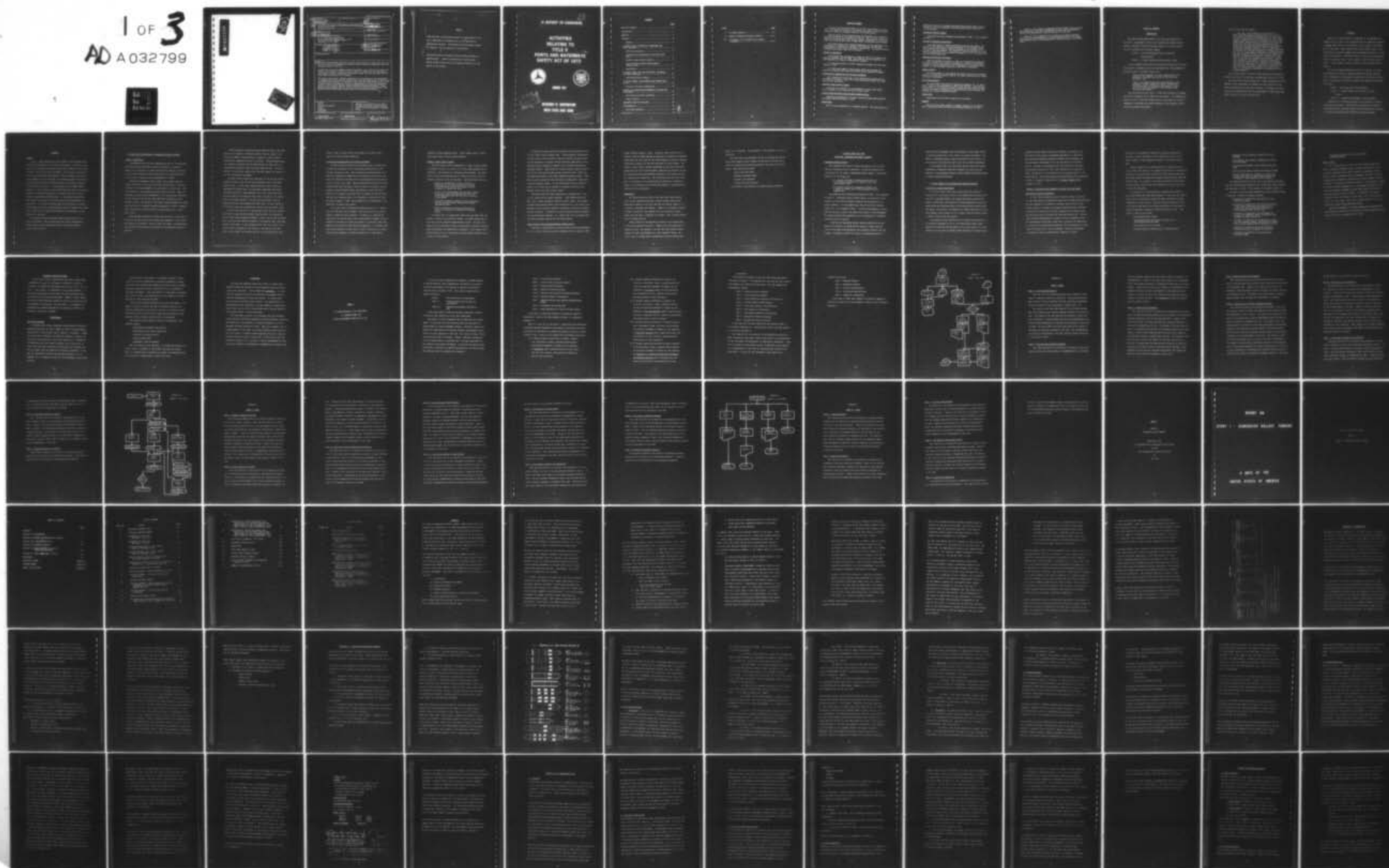

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16. Abstract

The Ports and Waterways Safety Act of 1972, was enacted on 10 July 1972. The purpose of the Act is to promote the safety of ports, harbors, waterfront areas, and navigable waters of the U. S.

Section 203 of the Act requires that the Secretary, for a period of 10 years following the enactment of Title II, make a report to Congress at the beginning of each regular session, regarding his activities under the Title and sets forth in some detail the matters to be covered.

The report begins with a general description of the approach to the development of standards and continues with progress that has been accomplished in those areas indicated in Section 203. The specific topics discussed under these areas are as follows: Safety of Navigation; Internat'l Regulations for Collision Avoidance; Domestic Vessel Traffic System; Vessel Bridge-to-Bridge Radiotelephone Comms; Maneuvering; Segregated Ballast Tankers; Pollution Prevention Regulations; IMCO Marine Pollution Conference; Tanker Outflow; and Spill-Risk Analysis.

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A REPORT TO CONGRESS

ACTIVITIES RELATING TO TITLE II PORTS AND WATERWAYS SAFETY ACT OF 1972

JANUARY 1973

DEPARTMENT OF TRANSPORTATION

UNITED STATES COAST GUARD

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EXECUTIVE SUMMARY

The Ports and Waterways Safety Act of 1972, was enacted on 10 July 1972. The purpose of the Act is to promote the safety of ports, harbors, waterfront areas and navigable waters of the United States.

Section 203 of the Act requires that the Secretary, for a period of ten years following the enactment of Title II, make a report to the Congress at the beginning of each regular session, regarding his activities under the Title and sets forth in some detail the matters to be covered.

The report begins with a general description of the approach to the development of standards and continues with progress that has been accomplished in those areas indicated in Section 203. The specific topics discussed under these areas are as follows:

Safety of Navigation

(a) Describes IMCO amendments to SOLAS '60 which will require navigational equipment such as radar, echo sounders and gyro-compass to be made mandatory for ships on international voyages.

(b) Describes purpose of traffic separation schemes that have been adopted by IMCO.

(c) States that LORAN-C could provide sufficient accuracy for vessels to maintain their positions within traffic separation schemes.

International Regulations for Collision Avoidance

IMCO produced the Convention on the International Regulations for Preventing Collisions at Sea, 1972, which revises and brings up to date the existing Convention.

Domestic Vessel Traffic System

Describes the authority and establishment of Coast Guard vessel traffic systems in San Francisco Bay and Puget Sound.

Vessel Bridge-to-Bridge Radiotelephone Communications

Regulations implementing the Vessel Bridge-to-Bridge Radiotelephone Act became effective January 1, 1973.

Maneuvering

Data is being acquired for an in-depth analysis. The Coast Guard has

published a Notice of Proposed Rule Making which would require certain vessels to have the maneuvering characteristics data of the ship in its pilot-house.

Segregated Ballast Tankers

This study has been completed and presented to IMCO. It is attached as Annex II.

Pollution Prevention Regulations

The Coast Guard has issued regulations governing the design, construction, and operation of vessels operating in the navigable waters and on onshore and offshore facilities engaged in the transfer of oil in bulk to and from vessels. The purpose of these regulations is to reduce the possibility of an accidental discharge of oil or oily waste during the normal operations.

IMCO Marine Pollution Conference

IMCO has decided to convene, in 1973, an international conference on marine pollution for purpose of preparing a suitable international agreement to place restraints on the contamination of the sea by ships, vessels or other equipment operating in the marine environment.

Tanker Outflow

The IMCO Assembly in 1971 adopted new vessel construction standards aimed at limiting the possible size of oil spills resulting from a tanker collision or grounding.

Spill-Risk Analysis

The Coast Guard contracted the Operations Research, Inc. to undertake a study for the development of spill-risk analysis. The objective of the study is to determine a method of selecting cost-effective combinations of protective equipment or regulations which will decrease the probability of spill-causing accidents.

CONCLUSIONS

Conclusions are set forth on page 20 of the Report.

ANNEXES

Annex I of the report presents a systems approach to the improvement of standards under the Ports and Waterways Safety Act of 1972.

Annex II is the Report on Segregated Ballast Tankers that the Coast Guard submitted to the IMCO Subcommittee on Ship Design and Equipment and the IMCO Subcommittee on Marine Pollution in June 1972.

Annex III is an Analysis of Oil Outflow Due to Tanker Accidents that the Coast Guard submitted to the IMCO Subcommittee on Ship Design and Equipment and the IMCO Subcommittee on Marine Pollution in November 1972.

REPORT TO CONGRESS

INTRODUCTION

The Ports and Waterways Safety Act of 1972, was enacted on 10 July 1972. The purpose of the Act is to promote the safety of ports, harbors, waterfront areas and navigable waters of the United States. The Act is divided into two parts, namely:

TITLE I - Ports and Waterways Safety and Environmental Quality

TITLE II - Vessels Carrying Certain Cargoes in Bulk

Title II amends Section 4417a of the Revised Statutes (46 USC 391a). This Section is commonly called the Tank Vessel Act. The statement of policy for Title II declares, inter alia,

> "That existing standards...of such vessels must be improved for the adequate protection of the marine environment." and

> "That it is necessary that there be established...comprehensive minimum standards of design, construction, alteration, repair, maintenance and operation to prevent or mitigate the hazards of life, property, and the marine environment."

The Tank Vessel Act gave the U.S. Coast Guard authority to develop and enforce standards for the safety of such vessels. The statement of policy in Title II now adds another facet to this authority in that it addresses a requirement for vessel standards for the purposes of protecting the marine environment.

Section 203 of the Act states:

> "Sec. 203. The Secretary of the Department in which the Coast Guard is operating shall, for a period of ten years following the enactment of this title, make a report to the Congress at the beginning of each regular session, regarding his activities under this title. Such report shall include but not be limited to (A) a description of the rules and regulations prescribed by the Secretary (i) to improve vessel maneuvering and stopping ability and otherwise reduce the risks of collisions, groundings, and other accidents, (ii) to reduce cargo loss in the event of collision, groundings, and other accidents, and (iii) to reduce damage to the marine environment from the normal operation of the vessels to which this title applies, (B) the progress made with respect to the adoption of international standards for the design, construction, alteration, and repair of vessels to which this title applies for protection of the marine environment, and (C) to the extent that the Secretary finds standards with respect to the design, construction, alteration, and repair of vessels for the purposes set forth in (A)(i), (ii), or (iii) above not possible, an explanation of the reasons therefor."

This initial report is therefore being submitted as required by Section 203, Title II, of the Ports and Waterways Safety Act of 1972.

The report which follows begins with a general description of the approach to the development of standards for the protection of the marine environment and a word about resources. The report will then continue with progress that has been accomplished in those areas indicated in parts A, B and C of Section 203.

APPROACH

When the U.S. Coast Guard was transferred to the Department of Transportation in 1967, it was recognized that the traditional emphasis on safety alone would not be consistent with the needs of the Department or the times. Other factors found to be of major concern in the regulation of the marine industry were environmental protection, facilitation and efficiency. Therefore, Title II of the Ports and Waterways Safety Act requires little, if any, change in what the Coast Guard is doing. It does, however, require a change in how the Coast Guard is doing it.

To meet this change required by Title II of the Act, a project was established to provide a systems approach to develop improved vessel standards for the purposes of protection of the marine environment. This project is outlined in Annex I and comprises three phases as follows:

- Phase I - Data Acquisition and Improvement
- Phase II - Problem Analysis and Selection of Alternatives
- Phase III - Regulation Development and Promulgation

Augmentation of existing personnel may be necessary in order to accomplish this project. Resources may be obtained as a result of reassignments from a workload analysis and the elimination of some of the workload presently being performed by program personnel.

PROGRESS

General

The U.S. Coast Guard has not been unaware of the problems attendant upon the protection of the marine environment. In point of fact, many of the regulations promulgated under Section 4417a of the Revised Statutes, prior to the present amendment, can be and are considered as regulations to maintain the integrity of the containment of bulk cargoes hazardous "to life, property, the navigable waters of the United States and the resources contained therein" and therefore responsive to the mandate of Title II. In the aftermath of the TORREY CANYON disaster in 1967, interest in the United States was high for the implementation of corrective measures at a national level and in international cooperation toward this goal. It is generally recognized that actions to be taken in both areas should be interdependent and compatible. To this end, the Coast Guard has been heavily involved in the deliberations of the Intergovernmental Maritime Consultative Organization (IMCO) directed toward the prevention and elimination of the pollution of the seas.

Much effort has been undertaken toward the protection of the marine environment. The following sections provide information on actions taken or being taken that relate to objectives stated in Section 203 of the Act.

To Reduce Risk of Collisions, Groundings and Other Accidents

Safety of Navigation

Considerable effort has been undertaken by IMCO to introduce measures and policies designed to incrase the safety of navigation. Among the most important are those requiring the compulsory carriage of navigational equipment and the application on a voluntary basis of the principle of ships routing and separation of traffic.

Navigational equipment such as radar, echo sounders and gyrocompass which have so far been carried at the discretion of the owner or master will be made mandatory for ships above a certain size. This is in addition to the presently required direction finder. These requirements take the form of amendments to the International Convention for the Safety of Life at Sea, 1960 (SOLAS 60) as approved by the Assembly of IMCO. In addition to the above, further amendments to SOLAS were approved by the Assembly requiring possession on board of adequate charts and nautical publications and by regulating the use of automatic pilots.

These amendments designed to reduce the incidence of collisions or groundings were ratified by the United States subsequent to the advice and consent of the Senate. They will come into effect, internationally, one year after ratification by two-thirds of the signatory nations to SOLAS 60.

Traffic separation schemes have been adopted by IMCO in 50 areas where there is dense or converging traffic, with the object of reducing the number of ships meeting on opposite or nearly opposite courses thus, lessening the risk of collision. Detailed descriptions are included in national maritime publications and charts and in a comprehensive publication which has been issued by IMCO. Since the subject is continuously under review, existing schemes are updated or new ones introduced as necessary.

Two major traffic separation techniques are used in the coastal confluence region; they are the harbor approach lanes, and coastal traffic lanes. In most cases, opposing one way traffic lanes are separated by a buffer zone. For the harbor approaches that extend more than fifty miles (approximately) out to sea, such as New York, the lane width is five nautical miles, and it narrows to one nautical mile at the harbor entrance. For the coast-wise traffic lane, as exemplified by the Santa Barbara-San Pedro lanes, the lane widths are one nautical mile each, separated by a two nautical mile buffer zone.

Loran-C holds promise as a navigational system that will provide sufficient accuracy by which vessels could maintain their positions within these traffic separation schemes. Loran-C may be used to assure that a ship can stay within the bounds of its shipping lane a very high percent of the time. If the accuracy of the "aid" is at least ± 0.25 nautical mile, 95 percent of the time for a one nautical mile lane width, and at least ±1.0 nautical mile for a five nautical mile lane

width, a ship can remain within the bounds of its traffic lane. Loran-C has this accuracy capability.

International Regulations for Collision Avoidance

An IMCO sponsored international conference held in October 1972 produced the Convention on the International Regulations for Preventing Collisions at Sea. This Convention revises and brings up to date the International Regulations for Preventing Collisions at Sea which are annexed to the Final Act of the International Conference on Safety of Life at Sea, 1960. The new Convention will come into force twelve months after the date on which at least 15 countries, the aggregate of whose merchant fleets constitutes not less than 65% by number of by tonnage of the world fleet of vessels of 100 gross tons and over have become parties to it, whichever is achieved first but not before January 1, 1976. The Convention will be submitted to the Senate for its advice and consent.

In the past these international regulations were not in convention form and could not be amended. The new Convention will permit changes through the IMCO procedures. In addition to updating the regulations and stating them in more understandable language, the new Convention increases the visibility ranges for navigation lights and requires more efficient sound signalling apparatus. It includes rules which induce mariners to take action to avoid collisions at an early time and rules applying to vessels navigating in or near traffic

separation schemes adopted by IMCO. These changes, when in effect, should help avoid collisions and groundings.

Domestic Vessel Traffic System

While the authority for establishment of vessel traffic systems is provided in Title I of the Act, it is felt these systems will be effective in the reduction of collisions and groundings. The Coast Guard has been developing methods for analyzing the need for such systems in specific ports and waterways. Some broad objectives are:

- Reduce the probability of ship collisions or groundings in ports and waterways and thereby reduce shipboard injuries and deaths and loss or damage to vessels and cargo.
- Protect ports and waterways from pollution caused by spills of petroleum products and other hazardous substances resulting from ship collisions or groundings.
- Facilitate waterborne commerce in ports and waterways by providing greatly improved all weather navigational aids.
- Protect shoreside facilities by reducing the number of collisions or groundings in adjacent waters.

In January 1970, an experimental Harbor Advisory Radar (HAR) was placed in service in San Francisco Harbor. It became operational in July 1972, with an improved communications network. By early 1973, there will be a new control center on Yerba Buena Island with improved radar surveillance and communications equipment. This Vessel Traffic Control Center will be a functionally reliable system capable of providing full time service.

The waters of Puget Sound were selected as the second major test site for Vessel Traffic Systems (VTS). The geographical configuration of Puget Sound is quite different from San Francisco Bay thus providing the opportunity to develop concepts generally applicable to long, relatively narrow channels as opposed to the concepts developed for congested harbors. Puget Sound has a great variety of marine traffic and is one of the world's great marine recreation areas. Small recreational boats abound, as do small commercial fishing vessels. Other marine traffic ranges from tugs and barges to deep-draft, ocean-going naval and merchant vessels. If the Trans-Alaska Pipeline becomes a reality it will also see an increase in tank-ship activity as one delivery point of oil from Valdez, Alaska.

The Puget Sound VTS became operational in September 1972. The initial system has two primary features: a VHF communications network, and a traffic separation scheme or traffic lanes. This system provides participating vessels with information as to the location and movement of other vessels, hazards to navigation, and unusual weather and sea conditions. In addition, we will be making general broadcasts to non-participating vessels; i.e., vessels that are not equipped with the radio equipment required for full participation.

Vessel Bridge-to-Bridge Radiotelephone Communications

Regulations implementing the Vessel Bridge-to-Bridge Radiotelephone Act, P.L. 92-63, which was signed by President Nixon on August 4, 1971,

became effective January 1, 1973. The basic intent of the Act is to provide a positive means whereby the operators of vessels can instantly communicate with each other by VHF radio-telephone in order to exchange information necessary for the safe navigation of their vessels. The Domestic Vessel Traffic Systems established by the Coast Guard incorporates the use of VHF radio-telephone communications and will utilize the bridge-to-bridge radiotelephone frequency as the primary circuit for conducting its operations. This legislation will not only contribute to the safety of life and property but should be a significant factor in the avoidance of collisions and thereby in the prevention of pollution of the environment.

Maneuvering

The limited historical data on the very large crude carriers (VLCC) do not establish that their accident record involving the manevuering element is any worse than that for smaller tankers; i.e., collisions, groundings and rammings. Based on a preliminary analysis of tanker casualties, there appears to be no correlation between tanker size and type or frequency of accident. Data is being acquired for an in-depth analysis.

Another aspect of the maneuvering problem is the qualification of the pilots handling the VLCC's. Where do they get experience in handling a VLCC? The problem is not that the large tankers cannot maneuver but that they maneuver in a less responsive manner, and hence, there is a human factor problem which requires training and

experience to overcome. The resolution of this problem is yet to be developed.

The Coast Guard has published a Notice of Proposed Rule Making which would require certain vessels of 1600 gross tons and over to have the maneuvering characteristics data of the ship in its pilothouse. These data would include:

Speed versus RPM tables

Minimum steerageway speed

Turning circle diagrams

Stopping time and distances

The replies to this proposal are presently being evaluated.

To Reduce Cargo Loss From
Collisions, Groundings and Other Accidents

Segregated Ballast Tankers

IMCO undertook nine areas of study in preparation for an international conference on marine pollution. The United States was the lead country for the study of segregated ballast tankers. The primary objectives of the study were:

- To evaluate the effect of design modifications on oil pollution abatement for a range of very large crude carriers; and
- To determine practical arrangements (designs) for a family of tankers with various segregated ballast capabilities.

The study has been completed and presented to IMCO. It is attached as Annex II. Segregated ballast tankers appear to be the most viable solution to the pollution problem created by the ballasting of the larger tankships. It also appears that this solution will remain a valid one in the foreseeable future. It would be presumptuous to state that the obstacles cited in the report with respect to the development of flexible barriers and separators or to the acceptance of shoreside facilities will be overcome.

In terms of the segregated ballast designs studied for the very large crude carriers, the double bottom design is clearly the most cost effective when both operational and accidental pollution are considered. The degree to which any version of segregated ballast is

cost effective is dependent upon the complexity of the design (which is directly proportional to the increase in capital investment), the amount of segregated ballast capacity afforded and the ability of a given design to mitigate both operational and accidental discharges.

At the present time, the Coast Guard believes that the national commitment to eliminate intentional discharge can best be met by adoption of the segregated ballast concept coupled with double bottoms to reduce accidental pollution.

To Reduce Damage to Environment from Normal Operations

Pollution Prevention Regulations

The United States Coast Guard, acting under the authority of Section 11(j) (now Section 311(j)) of the Federal Water Pollution Control Act, as amended (FWPCA), has issued regulations governing the design, construction, and operation of vessels operating in the navigable waters and contiguous zones of the United States, and governing the design, construction, and operation of onshore and offshore facilities engaged in the transfer of oil in bulk to and from vessels having a capacity of more than 250 barrels.

The purpose of these regulations is to reduce the possibility of an accidental discharge of oil or oily waste during normal vessel operations, during the bulk transfer of oil or oily wastes to or from vessels, or as a result of certain vessel accidents of limited energy.

Although the high energy collision or grounding is spectacular and may create locally severe environmental degradation, a significant and continuous degradation generally results from the frequent and less spectacular discharges of oil into the waters of the United States. Although not promulgated under the authority of the Ports and Waterways Safety Act of 1972, these regulations are expected to reduce the amount of oil discharged into the navigable waters of the United States. The regulations have been promulgated and are published in Part II, Volume 37, Number 246 of the Federal Register dated December 21, 1972.

Adoption of International Standards to Protect the Environment

IMCO Marine Pollution Conference

In 1967, IMCO launched an 18 point program covering both technical and legal aspects of problems arising from the TORREY CANYON disaster. The IMCO Assembly at its session in November 1968, which was especially convened to consider this program, approved measures designed to prevent the occurrence of similar incidents and to promote rapid and efficient action in dealing with them should they occur. The program included recommendations to improve pollution abatement action at international and national levels and to reinforce the application of clauses of the International Convention for the Prevention of Pollution of the Seas by Oil, 1954, as amended. IMCO has also decided to convene, in 1973, an international conference on marine

pollution for the purpose of preparing a suitable international agreement to place restraints on the contamination of the sea by ships, vessels or other equipment operating in the marine environment.

A major objective to be achieved by 1975 if possible but certainly within this decade is the complete elimination of international pollution of the seas by oil as well as by other noxious substances. The United States has pushed this objective internationally under the aegis of IMCO. As a result of its efforts and those of other major maritime nations, IMCO now has this objective as its principal goal for the 1973 Conference.

In preparation for this Conference, agreement was reached to have nine studies under way simultaneously. In each case the study is being led by an individual country with other countries furnishing information as they are able. IMCO now is moving forward on a nine front basis rather than on the single front basis as in the past to produce a meaningful convention on marine pollution in 1973. The areas of study are as follows:

- Segregated ballast tankers.
- Dual purpose tanks with means to isolate oil or noxious materials from water.
- The retention of oil on board.
- Cleaning tanks for ballast prior to vessel sailing.

- Retention of dirty ballast on board for in port disposal.

- Environmental and financial consequences of pollution from ships.

- Collection and disposal of ship generated dry garbage.

- Ship generated sewage treatment and holding systems.

- Pollution caused by the discharge of noxious substances other than oil through normal operational procedures of ships engaged in bulk transport.

As background material for the first five studies listed above, the Coast Guard made an analysis of oil outflow from tanker accidents and presented it to IMCO. This analysis is attached as Annex III.

The draft convention being developed by various technical bodies of IMCO will include the following subjects:

- Prevention of pollution of the seas by oil discharged from ships.

- Prevention of pollution of the sea by bulk liquid or dry noxious substances other than oil discharged from ships (excluding the disposal of shore-generated wastes into the sea).

- Prevention of pollution of the environment resulting from inadequate design, construction and equipment of ships carrying oil.

- Prevention of pollution of the environment resulting from inadequate design, construction and equipment of ships carrying noxious substances in bulk.

- Prevention of pollution of the sea by noxious substances carried in packages or containers.

- Prevention of pollution of the sea by ship-generated sewage.

Prevention of pollution of the sea by ship-generated garbage.

Tanker Outflow

At its October meeting in 1971, the IMCO Assembly adopted new vessel construction standards aimed at limiting the possible size of oil spills resulting from a tanker collision or grounding. Future tankers, built in accordance with new standards, will have a limit on the hypothetical maximum oil outflow from a single incident involving grounding or collision of 30,000 cubic meters. This applies to tankers up to about 420,000 deadweight tons. The maximum permissible oil outflow then gradually increases to 40,000 cubic meters at one million deadweight tons and levels off there. In addition, the proposed amendments limits the volume of a wing tank to 75% of the maximum outflow as set forth above. The size of a center tank will not be permitted to be bigger than 40,000 cubic meters.

These 1971 amendments to the 1954 International Convention for the Prevention of Pollution of the Seas by Oil were transmitted to the Senate for advice and consent on May 5, 1972.

Standards Found Not Possible

Section 203 of the Act requires that the report include those "standards with respect to the design, construction, alteration, and repair of vessels for the purposes set forth in (A)(i), (ii), or (iii) ...not possible, an explanation of the reasons therefor." It was stated previously that much effort has been undertaken toward the protection of the marine environment. However, current studies have not provided sufficient evidence to focus on any particular set of standards or regulations. For this reason, it is premature to designate any standard developed for the purposes set forth as not possible or practical to enforce.

Miscellaneous

Spill-Risk Analysis

The Coast Guard, having recognized the seriousness of spills of hazardous materials, has taken a number of steps to prevent further deterioration of the situation and to improve it if possible. Before the Coast Guard can exercise its statutory authority to improve the situation it must know how to select the regulations or combination of regulations that truly lessen accidents, how to concentrate on those situations where accidents are potentially most damaging, and how to evaluate costs and benefits of alternative programs. To this end, the Coast Guard contracted the Operations Research, Inc. in November 1972, to undertake a study for the development of spill-risk analysis.

The objective of the study is to determine a method of selecting cost-effective combinations of protective equipment or regulations which will decrease the probability of spill-causing accidents. Only spills resulting from hull rupturing are to be considered in the early work phases. Since the rupture of a ship tank is necessary for a spill to occur, the probability of a spill equates to the probability of a hull-rupturing accident.

The spill-risk analysis problem is very large and complex. The number of factors involved, the lack of knowledge concerning the relative significance of each factor, the lack of a method for handling these factors, and the need for gathering and analyzing large amounts of data concerning them all add to its magnitude.

The following general phases of work are contemplated in the complete program:

- Methodology development and planning.
- Demonstration and limited application.
- Extension and generalization.
- Complete application.
- Management system development.

The first phase has been completed. It studied the general problem to obtain a knowledge of the problem, developed the general logic of a methodology for handling the problem, and formulated plans for the second, or demonstration, phase of the work.

CONCLUSIONS

The Ports and Waterways Safety Act of 1972 is a major step in promoting safety and protecting the environmental quality of United States ports and waters. The Act emphasizes prevention. It recognizes the problems of pollution of the marine environment from the maritime transportation of polluting cargoes. It requires both better vessels and better traffic control. The regulations to be developed under this legislation will apply equally to vessels documented under the laws of the United States and to foreign vessels in the navigable waters of the United States.

The Coast Guard continues to be concerned with the increasing safety hazards of maritime transportation and with pollution resulting from operation of and casualties to vessels carrying oil or other hazardous polluting substances in bulk. While not a complete list of accomplishments in this area, this report highlights Coast Guard concern and actions. A workable systems approach has been developed to continue effective actions in this field. As the contract with the Operations Research, Inc., continues, it may be advantageous to alter the plan of approach as improvements in methodology are brought forth.

ANNEX I

A SYSTEMS APPROACH TO THE IMPROVEMENT

OF STANDARDS UNDER THE

PORTS AND WATERWAYS SAFETY ACT OF 1972

A project has been established to undertake a systems approach to develop improved vessel standards for the purpose of protecting the marine environment by eliminating or reducing the hazards of carrying certain cargoes in bulk. This project comprises three phases as follows:

Phase I	Data Acquisition and Improvement
Phase II	Problem Analysis and Selection of Alternatives
Phase III	Regulation Development and Enforcement

These phases would at times be underway concurrently; however, no definite time schedule has as yet been established.

The project is heavily dependent upon reliable data for support. Phase I is directed toward providing this data and increasing its effectiveness for better management analysis. Efforts to improve our methods of accumulating and processing casualty and management information have been underway for some time. As a result of these efforts reasonably good data is available. However, additional information will be required which is contingent upon a further improvement of our casualty investigation procedures. To provide the required information and at the same time commence improvement of its effectiveness, the following tasks were deemed to be necessary:

Task 1 - Gross Casualty Analysis

Task 2 - Casualty Data Collection Analysis

Task 3 - Program Workload Analysis

Task 4 - Resource Allocation Analysis

Task 5 - Casualty Data Collection Procedures Analysis

Task 6 - Improved Casualty Investigation

Task 7 - Improved Casualty Data Handling Methods-System Design

Task 8 - Programming and Systems Test

Task 9 - Ready Availability of Data to Project Groups

A flow chart of these task elements is attached as Appendix I. Objectives of each for the task elements in Phase I is attached as Appendix II.

Phase II is the core of the project. Groups have been established to develop improved standards for the purpose of protecting the marine environment by eliminating or reducing the hazards of carrying certain cargoes in bulk. There are five groups with the following objectives:

(a) To develop feasible alternatives of design, construction, maintenance, repair, personnel qualifications and operating standards of vessels for the reduction of <u>groundings</u> and/or resulting pollution and to determine the cost, benefits, practicality and effectiveness of each alternative.

(b) To develop feasible alternatives of design, construction, maintenance, repair, personnel qualifications, and operating standards of vessels for the reduction of collisions and/or resulting pollution and to determine the cost, benefits, practicality and effectiveness of each alternative.

(c) To develop feasible alternatives of design, construction, maintenance, repair, personnel qualifications and operating standards of vessels for the reduction of fire and explosion and/or resulting pollution and to determine the cost, benefits, practicality and effectiveness of each alternative.

(d) To develop feasible alternatives of design, construction, maintenance, repair, personnel qualifications, and operating standards of vessels for the reduction of structural failures and/or resulting pollution and to determine the cost, benefits, practicality and effectiveness of each alternative.

(e) To develop feasible alternatives of design, construction, maintenance, repair, personnel qualifications, and operating standards of vessels for the reduction of accidental or intentional operational discharges and resulting pollution and to determine the cost, benefits, practicality and effectiveness of each

alternative.

Each group will analyze its objective and develop appropriate alternative solutions. To accomplish this goal specific task elements were deemed to be required for each group. The task elements were stipulated as follows:

Task 1 - Casualty Situation Analysis

Task 2 - Failure Reduction Analysis

Task 3 - System Sensitivity Analysis of Alternatives

Task 4 - Internal Resource Needs Analysis

Task 5 - Practicality Analysis of Alternatives

Task 6 - Cost Analysis of Alternatives

Task 7 - Cost-Benefit Analysis of Alternatives

Task 8 - Alternative Evaluation Analysis

Task 9 - Alternative Selection Decision

A flow chart for the task elements for each group in Phase II is attached as Appendix III. Objectives for each of the task elements are attached as Appendix IV.

Upon completion of the selection of the preferred alternative of those developed by each group, certain tasks remain to be accomplished for the development and promulgation of appropriate regulations. Phase III is proposed for this purpose as well as additional tasks required to be accomplished in order that the regulations may be proper and enforceable. To carry out this assignment, task elements were

stipulated as follows:

Task 1 - Workload Analysis

Task 2 - Regulation Drafting

Task 3 - Training Needs Analysis

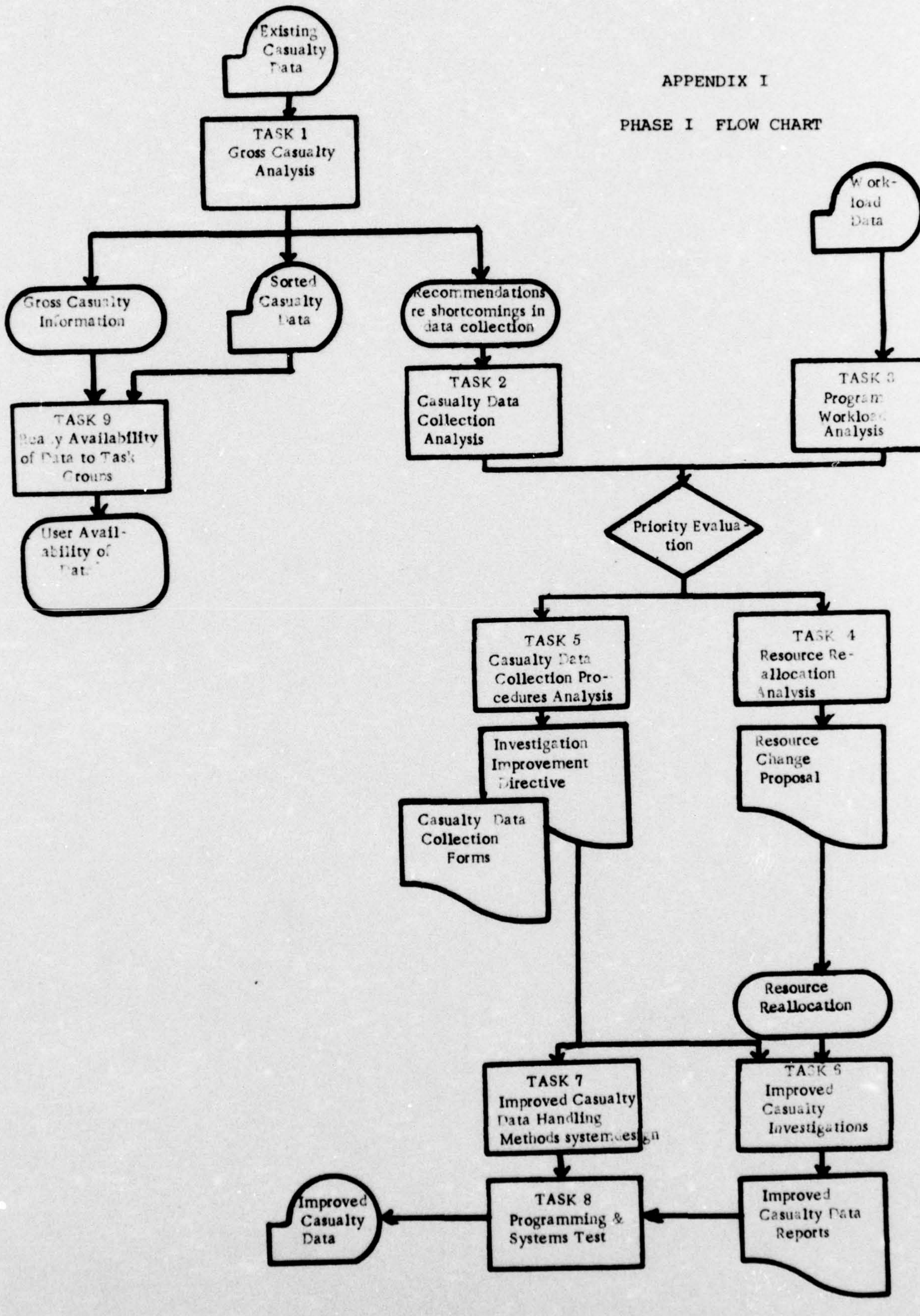
Task 4 - Develop R&D Specifications

Task 5 - Regulation Promulgation

A flow chart of these task elements is attached as Appendix V. Objectives for each of the task elements in Phase III are attached as Appendix VI.

APPENDIX I

PHASE I FLOW CHART



APPENDIX II

PHASE I TASKS

Task 1 - Gross Casualty Analysis

This task is to sort existing casualty data according to major types of casualties resulting in pollution. These groups would probably consist of those casualties involving collisions, groundings, structural failures, fires, explosions, transfer spills, etc.

The inputs to this task would consist of the existing casualty data, the necessary funds, and the required personnel to perform the task. The outputs of the task would be the groupings of gross casualty information, a sorted casualty data file and recommendations concerning needed improvements to overcome the shortcomings in the existing data. The final output from this group would be the release of the additional personnel provided for the task. The recommendations concerning the shortcomings in the data collection would provide one of the inputs to Task 2.

Task 2 - Casualty Data Collection Analysis

This Task would have as its objective the analysis of the shortcomings and data and the providing of recommendations for overcoming

these shortcomings together with the resource needs to accomplish the recommendations. Inputs to this task would consist of the recommendations, the necessary personnel to accomplish the task and the necessary funding. Outputs from this task would consist of recommendations and manpower and dollar resource requirements for overcoming the shortcomings in the data as well as the release of the additional personnel required to perform the task. The recommendations would be combined with the output of Task 3.

Task 3 - Program Workload Analysis

This task would have as its objective the performance of an analysis of the existing program workload and the assessment of the resources presently dedicated to the various workload facets. Inputs to this task would consist of existing workload data, personnel and dollar resources for accomplishing the task. The outputs of the task would consist of an assessment and analysis of the present resources being dedicated to various program workload efforts as well as the release of the personnel assigned to accomplishing the task. The outputs of this Task and Task 2 would be the subject of a decision concerning the priority of accomplishing the improved data collection as versus the priority of the various facets of existing program workloads. Upon completion of this priority evaluation and decision the outputs and priority listing would be furnished to Tasks 4 and 5.

Task 4 - Resource Reallocation Analysis

This task would have as its objective determining the reallocation of resources within the program to meet the priorities established in the preceding step. Inputs to this task would be the priority evaluation, workload analysis listing, personnel and dollars necessary to accomplish the task. The output of the task would be a Resource Change Proposal (RCP) directing the reallocation of resources.

Task 5 - Casualty Data Collection Procedures Analysis

This task would have as its objective the analysis of our existing casualty collection efforts and redirecting these efforts to meet the requirements as set in Task 2. The input to this task would consist of the casualty data collection improvement needs, personnel and dollars necessary to accomplish the task. The outputs of this task would consist of a directive to the field indicating the improvements required in casualty data collection efforts, the revised casualty data collection forms and procedures and the release of the personnel assigned for the accomplishment of this task. The outputs of Task 4 and 5 would ultimately reach the field in the form of requirements for changes in casualty data collection and forms for the accomplishment of this change together with direction concerning the utilization of field resources for intensifying data casualty collection and for reducing other efforts to provide the necessary resources. Some field

and the release of the personnel assigned to the Task.

Task 6 - Cost Analysis of Alternatives

This Task would have as its objective the development of total cost analysis for each of the alternatives recommended as a result of Task 2. Inputs to this Task would consist of the failure reduction analysis accomplished in Task 2, Internal Resource Needs developed in Task 4, cost data obtained from sources external to the commercial vessel safety program, and personnel and dollar resources necessary for the accomplishment of the Task. Outputs of this Task would consist of a cost analysis of each of the alternatives addressing the government cost to implement the alternative, the owner's cost to comply with the alternative, the owner's savings due to prevention of casualties, and third party savings resulting from the reduction or elimination of the casualties. Other outputs would include recommendations concerning data requirements, R&D needs, and the release of the personnel assigned to the Task.

Task 7 - Cost Benefit Analysis of Alternatives

This Task would have as its objective the development of a cost-benefit analysis for each of the alternatives developed in Task 2. Inputs to this Task would consist of the benefit analysis developed in Task 2, the cost analysis developed in Task 6 and the dollar and personnel resources necessary to accomplish this Task. Outputs from this Task would consist of the cost-benefit analysis for each alternative,

recommendations concerning research and development needs, recommendations concerning additional data needs, and the release of the personnel assigned for the completion of the Task.

Task 8 - Alternative Evaluation Analysis

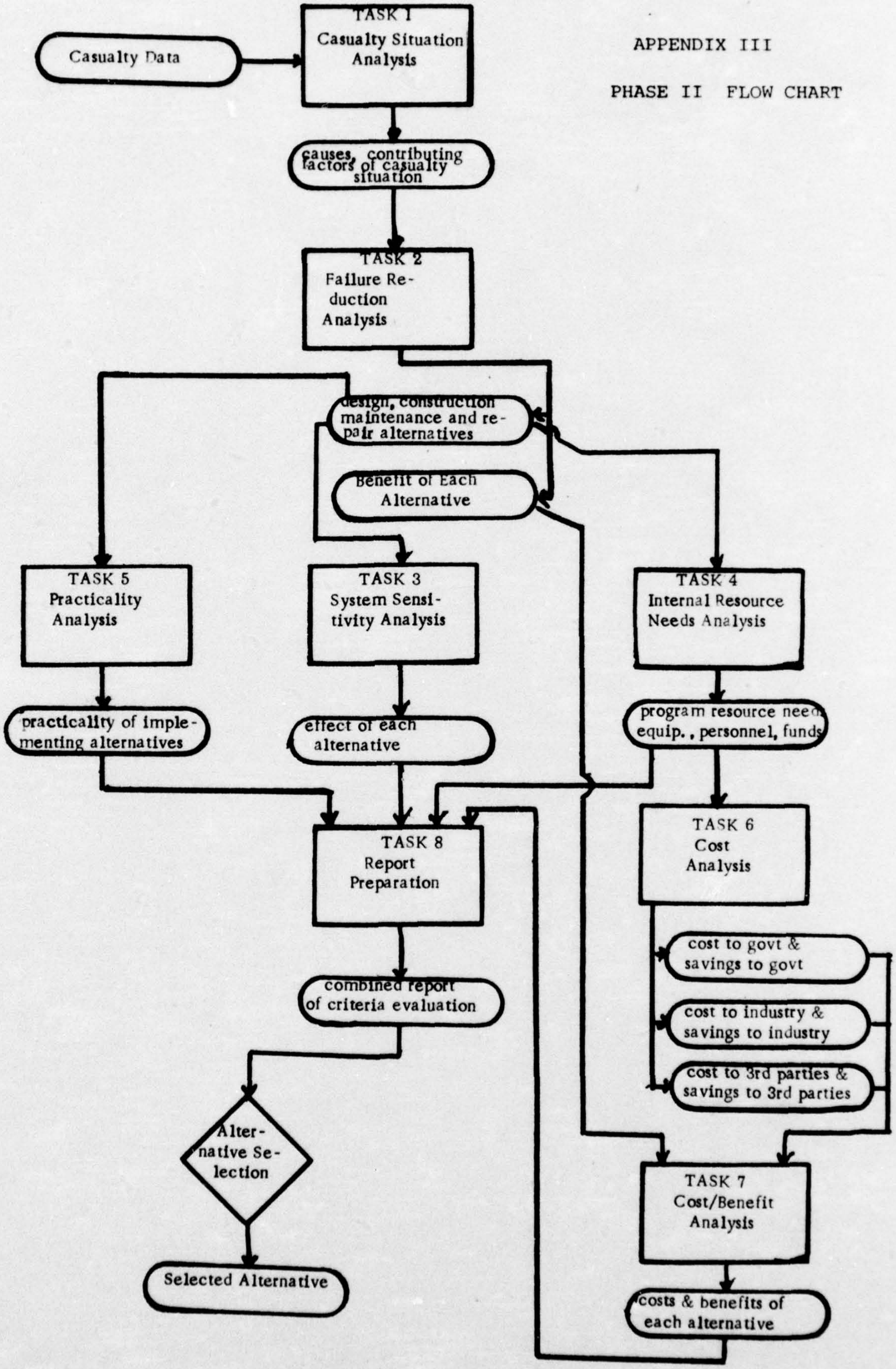
This Task would have as its objective the preparation of a complete analysis of each of the alternatives in the preceding series of tasks. Inputs to this Task would consist of the analysis outputs of Tasks 4 through 7, and the necessary personnel and dollar resources to accomplish the Task. The outputs of this Task would consist of the complete analysis package for each of the alternatives addressed in the analysis output of Task 2 and the release of the resources assigned to the accomplishment of this Task.

Task 9 - Alternative Selection Decision

This decision consists of the review of the complete analysis package and the selection of the preferred alternative. The output of this decision is the selection of the preferred alternative.

APPENDIX III

PHASE II FLOW CHART



APPENDIX IV

PHASE II TASKS

Task 1 - Casualty Situation Analysis

This Task would address one of the casualty situations indicated by the gross casualty analysis. This Task would have as its objective the detailed identification of the role played by various types of failures both mechanical and personnel contributing or causing this type of casualty. Inputs to this Task would consist of the available casualty data concerning the casualty situation both in the form of printouts and back up hard copy casualty files, personnel and dollar resources necessary to accomplish the task. Output from this Task would consist of detailed analyses of the causes and contributing factors of the casualty situation, recommendations concerning shortcomings in the casualty data, recommendations concerning research and development needs, and the release of the personnel assigned to the Task.

Task 2 - Failure Reduction Analysis

This Task would have as its objective the development and analysis of alternative means of minimizing or eliminating the failures causing or contributing to the particular type casualty situation. Inputs to this Task would consist of the failure analyses developed in Task 1 and personnel and dollar resources necessary to accomplish the

Task. Outputs from this Task would consist of a detailed analysis of alternatives for the elimination or reduction of the identified failures. These alternatives would consist of changes in the vessels' design, improvements in vessels' construction, changes in operating procedures including crew skills or competence, improvements in vessel maintenance, and changes in vessel equipment. The benefit to be obtained by the adoption of each alternative would be included for each type of vessel (i.e., petroleum tankers, liquified gas carriers, bulk chemical carriers, etc.). Other outputs would include recommendations concerning shortcomings in available data, recommendations concerning necessary research and development efforts, and the release of personnel supplied for the accomplishment of this Task.

Task 3 - System Sensitivity Analysis of Alternatives

This Task would have as its objective the analysis of the sensitivity of the entire marine transportation system to changes indicated by the adoption of each of the alternatives recommended in Task 2. Inputs to this Task would consist of the analysis performed in Task 2, improved casualty data resulting from the accomplishment of Task 6 of Phase I and necessary dollar resources for the accomplishment of the Task. Outputs of this Task would be the sensitivity analysis of each of the alternatives, recommendations concerning shortcomings in the casualty data recommendations concerning necessary R&D, and the release of the personnel assigned to the Task.

Task 4 - Internal Resource Needs Analysis

This Task would have as its objective the analysis of the quantity and quality of program resources required to accomplish the alternatives recommended in Task 2. This would include analysis of skills required on the part of program personnel, new test and inspection equipment required for program personnel, and new educational disciplines required within the program to insure compliance. Inputs to this Task would consist of the failure reduction analysis alternatives from Task 2 and personnel dollar resources necessary to accomplish the Task. The outputs of this Task would consist of the internal resource need analysis for each of the alternatives, recommendations concerning additional data needs, recommendations concerning additional research and development needs, and the release of the personnel assigned to the accomplishment of this Task.

Task 5 - Practicality Analysis of Alternatives

This Task would have as its objective the assessment of the practicality of instituting each of the recommended alternatives. Inputs to this Task would be the sensitivity analysis performed in Task 3, improved casualty data accomplished as a result of Task 6 of Phase I and the personnel and dollar resources necessary to accomplish the Task. Outputs from this Task would be the practicality analysis of each of the alternatives, recommendations concerning shortcomings in the available data, recommendations concerning necessary research and development,

and the release of the personnel assigned to the Task.

Task 6 - Cost Analysis of Alternatives

This Task would have as its objective the development of total cost analysis for each of the alternatives recommended as a result of Task 2. Inputs to this Task would consist of the failure reduction analysis accomplished in Task 2, Internal Resource Needs developed in Task 4, cost data obtained from sources external to the commercial vessel safety program, and personnel and dollar resources necessary for the accomplishment of the Task. Outputs of this Task would consist of a cost analysis of each of the alternatives addressing the government cost to implement the alternative, the owners cost to comply with the alternative, the owners savings due to prevention of casualties, and third party savings resulting from the reduction or elimination of the casualties. Other outputs would include recommendations concerning data requirements, R&D needs, and the release of the personnel assigned to the Task.

Task 7 - Cost Benefit Analysis of Alternatives

This Task would have as its objective the development of a cost-benefit analysis for each of the alternatives developed in Task 2. Inputs to this Task would consist of the benefit analysis developed in Task 2, the cost analysis developed in Task 6 and the dollar and personnel resources necessary to accomplish this Task. Outputs from this Task would consist of the cost-benefit analysis for each alternative,

recommendations concerning research and development needs, recommendations concerning additional data needs, and the release of the personnel assigned for the completion of the Task.

Task 8 - Alternative Evaluation Analysis

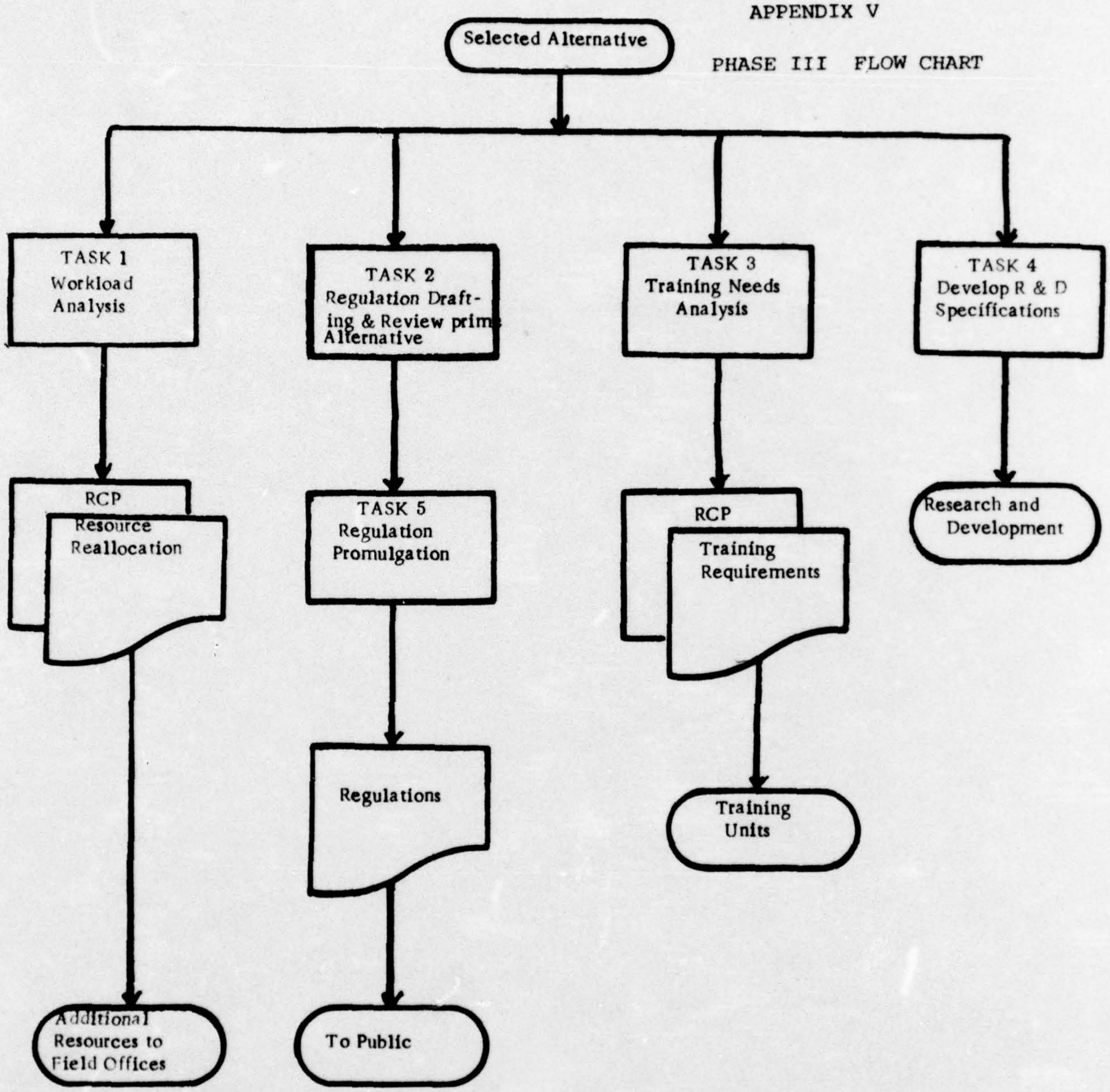
This Task would have as its objective the preparation of a complete analysis of each of the alternatives in the preceeding series of tasks. Inputs to this Task would consist of the analysis outputs of Tasks 4 through 7, and the necessary personnel and dollar resources to accomplish the Task. The outputs of this Task would consist of the complete analysis package for each of the alternatives addressed in the analysis output of Task 2 and the release of the resources assigned to the accomplishment of this Task.

Task 9 - Alternative Selection Decision

This decision consists of the review of the complete analysis package and the selection of the preferred alternative. Outputs of this decision of the selection of the preferred alternative.

APPENDIX V

PHASE III FLOW CHART



APPENDIX VI

PHASE III TASKS

Task 1 - Workload Analysis

This Task has as its objective the analysis of program workload together with the analysis of increased workload resulting from the selection of the prime alternative. Inputs to this Task are the complete alternative evaluation analysis, the indication of the selected prime alternative, the workload data file, and the personnel and dollar resources necessary to accomplish this Task. The outputs of this Task are a Resource Change Proposal for the subsequent budget stage indicating the additional resources required, the reallocation of present resources and the release of the additional personnel assigned for this Task.

Task 2 - Regulation Drafting

This Task has as its objective the drafting of regulations for implementing the prime alternative selected. Inputs to this Task are the alternative evaluation analysis, the indication of the selected alternative, and the personnel and dollar resources necessary for accomplishing this Task. Outputs of this Task are the draft regulations and the release of the additional personnel assigned for this Task.

Task 3 - Training Needs Analysis

This Task has as its objective the development of the analysis of additional training needs for program personnel for accomplishing the selected alternative. Inputs to this Task are the alternative evaluation analysis and the indication of the selected alternative together with the necessary personnel and dollar resources for accomplishing the Task. Outputs from this Task are an RCP for training requirements, the additional personnel and dollar resources required for accomplishing this training and the release of the additional personnel assigned for the accomplishment of this Task.

Task 4 - Development of R&D Specifications

This Task has as its objective the production of research and development specifications indicating additional R&D needs. Inputs to this Task are the alternative evaluation analysis and dollar and personnel resources necessary to accomplish this Task. The outputs of this Task are an RCP indicating detailed specifications concerning additional research and development needs and an RCP for the dollar resources required to perform the necessary research and development. The third output from this Task is to release the personnel assigned to the Task.

Task 5 - Regulation Promulgation

This Task has as its objective a promulgation of the regulations for implementing the selected alternative. The inputs to this Task are

the draft regulations developed in Task 2 and the personnel and dollar resources necessary to accomplish the Task. The outputs to this Task are the promulgated regulations and the release of the additional personnel assigned to the Task.

ANNEX II

REPORT ON

SEGREGATED BALLAST TANKERS

Submitted to the

IMCO Subcommittee on Ship Design and Equipment

and the

IMCO Subcommittee on Marine Pollution

in

June 1972

REPORT ON

STUDY I - SEGREGATED BALLAST TANKERS

A NOTE BY THE

UNITED STATES OF AMERICA

Note by the United States

Report on

Study I - Segregated Ballast Tanker

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SYNOPSIS

The study of segregated ballast tankers reported upon herein was prepared for submission to the IMCO Sub-committee on Ship Design and Equipment in accordance with previous notes by the United States, DE VII 2/4 and OP X/2/5. This study is one of the nine study areas agreed upon at the tenth meeting of the Sub-committee on Marine Pollution and, accordingly, its principal results should be considered in conjunction with results from each of the other studies, notably studies II, III, IV, V, and VI.

The principal features of the study are summarized herein. It is recommended that a thorough review of the entire study be made since the results are velieved to be subject to further analysis and interpretation beyond that which is possible here, particularly in regard to those data concerned with estimated effectiveness for pollution abatement. The study is divided into the following principal sections:

I Introduction

II Design and Engineering Summary

III Construction Costs

IV Economic Analysis

V Degree of Effectiveness for Pollution Abatement

VI Other Operational Factors

Before summarizing the principal results from each of these sections, the following general points must be made:

- This study has only concerned itself with the construction of new large crude carriers. The various design features, estimated ship prices, and economics are not applicable to conversions of existing ships. Even for the construction of new handy size product tankers, differences in cubic requirements, ballast requirements, trading patterns, and general marine economics could provide answers sufficiently different so as to make estimates herein inapplicable.

- Whereas the results given may be considered representative for large crude tankers in general, they should not be regarded as optimum either for the base case conventional designs or for the segregated ballast design variations. Further design refinement of any particular type of large crude tanker would be possible. Accordingly, the results should be viewed with this in mind.

- It is evident throughout the study that the level of ballast required for safe operation of a large crude tanker is an extremely important parameter to which both economics and pollution effectiveness are extremely sensitive. While this study contains comments on ballast level, it has not attempted to answer the complex question of what constitutes an acceptable ballast level. This involves considerations of ship design, trade routes, etc. which are beyond the scope of this study. Instead the study has tried to give an

indication of the sensitivity of the major variables to this parameter. It should also be noted that nearly all modern large crude tankers of freeboard draft design already possess a significant segregated ballast capability although not sufficient for general operation.

The ship designs prepared include thirteen different cases, twelve of which are shown diagrammatically in Figure 1. The one case not shown is a double skin variation of a 250M DWT in which the side skins and double bottom conform to the IMCO damage definitions; i.e., side skin width equal to B/5 and double bottom height equal to B/15. This case was dropped from further study when it was determined that the resulting design lacked stability, both intact and under damaged conditions. By reference to Figure 1 it can be seen that the principal ship design characteristics are:

1. three base ships of 120M, 250M, and 500M DWT each of which:
   - are of freeboard draft design
   - meet the IMCO outflow criteria
   - have cargo capacities for 38° API cargo on a long voyage
2. with two basic variations of segregated ballast levels to produce ballast displacements of either 45% or 60% of full load displacement as compared to a value on the order of 20-25% for the base case ships
3. double bottoms with segregated ballast (B-type designs)
4. double sides with segregated ballast (D-type design)

5. double skins with segregated ballast (C-type design)
6. single skins with segregated ballast in alternate wing tanks (E-type designs)

The summary table gives the principal results of the study. These results are grouped in such a way as to show the principal findings for various types of design changes regardless of ship size. The summary table also shows the particular section and/or table(s) containing more detailed information on each aspect of the study. The following explanatory comments to the summary table are considered pertinent:

- To understand *Description of Design Change* (column 1) and *DWT and Design* (column 2) refer to Figure 1.

- Segregated Ballast Displacement (column 3) refers to that level of ballast displacement (as a percent of full load displacement) which each particular case can attain using only segregated ballast. Those cases in which a value of 45% is shown were designed for that specific amount of segregated ballast. Consequently, when evaluated in terms of a 60% ballast level, it is necessary to use additional ballast in cargo tanks to meet that figure. In spite of this, the ships designed to the 45% ballast levels have been evaluated as to pollution effectiveness using normal ballast handling procedures for the additional amount of ballast needed to achieve a level of 60%.

- Percent Increase in Ship Price (column 4) and Percent Increase in Required Freight Rate (RFR) (column 5) should be self-explanatory. It should be noted, however, that in column 5 the values shown take the average of separate estimates made both for long and short voyages.

- Operational Pollution (column 6) shows a range of values as a percent of operational pollution which has been estimated for the base ship of similar DWT. For example, the values of 13-31% for design 250 E-2 represent an estimated operational discharge of between 13 and 31% of that which would occur with the base ship, 250-A IMCO. The range reflects both a range of ballast displacement between 45 and 60% of full load displacement, and the two tank washing assumptions described in the report.

- Columns 7 and 8 show estimates of relative accidental pollution from strandings and collisions as a percent of the estimated outflow which might occur in a similar accident to the base ship of similar DWT. For example, the value of 161% for 250 E-2 represents an estimated outflow 161% of that which would occur to the base ship 250-A IMCO, in a similar stranding accident.

The following general observations concerning the results in the summary table may be made:

- Any of the segregated ballast designs studied produce an increase in ship price and in RFR. The ship prices and values of RFR are definitely sensitive to the level of segregated ballast capacity and they increase as more complex ship arrangements are introduced.

- For any given design type the increases in ship price and RFR are sensitive to the proportions of the base ship. The 120M, 250M, and 500M DWT base ships are not geometrically proportional. For instance, compare increases for designs 250 E-1 to 500 E-1, and designs 120 C to 250 C.

- The estimated degree of effectiveness of operational pollution abatement (column 6) definitely appears to be improved by features of the types studied, and it also appears sensitive both to ballast level and method of tank washing. It is important to note, however, that in none of the cases studied is the degree of effectiveness total as may be commonly supposed for segregated ballast tankers. Furthermore, as explained in the study, the level of effectiveness is strongly dependent upon that which can be achieved in the base ship designs. This determination is the subject of IMCO Study III and, accordingly, the results shown in the present study should be interpreted in the light of that study. It should also be noted that the data base for the effectiveness of double bottom designs in reducing operational pollution is limited compared to that for single bottom tankers.

- The degree of effectiveness in accidental pollution (columns 7 and 8) indicates that none of the designs produce a high degree of effectiveness against both strandings and collisions. These data show that for many of the designs, the expected outflow, particularly in a stranding may increase over that which would occur in the base ship under similar circumstances.

From the summary table it will be apparent that a proper analysis and interpretation of the data in columns 6, 7, and 8 dealing with estimated pollution effectiveness involves consideration of the trade-offs between these various factors. In Section V C of the study further data are presented showing varying combinations of assumptions as to the magnitude of accidental pollution from strandings and collisions and the sensitivity thereto. The results of a wide range of assumptions as to these parameters are given in Section V C showing estimated relative outflows and cost effectiveness for each of the designs over the range of damage assumptions and ballast levels. From a review of that Section it will become apparent that for most of the designs a further trade-off must be considered since few offer reasonable protection over all ranges of possible assumptions.

Another important factor in interpreting these data is the degree to which other accident prevention measures now being studied by IMCO will tend to be effective in mitigating the one type of accident or the other; for instance, traffic separation schemes, navigation equipments, officer training, etc.

In regard to the values shown as to degree of effectiveness in pollution abatement, these values should be regarded principally as being relative in nature. The determination of the estimated outflow values particularly for the accidental situation were made on the basis of a number of assumptions which are described in the report. It is hoped that these assumptions have been sufficiently explicit so that further analysis based on other assumptions may be made.

Section VI provides a brief discussion of certain practical operating factors which could not be directly reflected in the economics due to lack of sufficient experience or data with ships of the type studied. Principal amoung these are the impact of larger freeboard resulting from various segregated ballast levels which will have an adverse effect upon ship handling, mooring, and piers. The possible problems from sludge build-up in the double bottoms due to ballast were also not quantified. The favorable effects in regard to tank cleaning and turn around time for each of the design types have been included in the study's economic and pollution effectiveness estimates.

Finally, this study provides a data base from which an overall assessment can be drawn for the evaluation of tanker design criteria in conjunction with the other five studies. It is beyond the scope of this study to attempt such an evaluation at this time.

SUMMARY TABLE (1)

SHIPS & BALLAST ASSUMPTION			ECONOMICS		ESTIMATED POLLUTION EFFECT		
Description of Design Change	DWT & Design	Segregated Ballast Δ (2)	% Increase in Ship Price	% Increase in RFR (3)	Operational Pollution as % of Base Ship (4)	Accidental Pollution as % of Base Ship: Stranding (5)	Accidental Pollution as % of Base Ship: Collision (5)
Column (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1) Single Skin	250 E-1	45%	4.2	4.6	20-51	146	79
	500 E-1	45%	9.0	8.8	19-58	Not Available	Not Available
	250 E-2	60%	9.8	10.8	13-31	161	66
2) Double Bottom	250 B-1	40%	6.4	6.1	28-47	54	105
	250 B-2	45%	8.7	8.5	2-41	46	101
3) Double Sides	250 D	60%	10.9	11.6	13-31	247	56
4) Double Skin	120 C	60%	22.9	20.5	1-5	Not Available	Not Available
	250 C	60%	17.5	17.2	2-4	85	70
	250 F	100%	------------Not Estimated		- Design not feasible due to insufficient stability--------------		
5) Discussion Section	II	II, IV, V	III, IV	IV	V A	V B, V C	V B, V C
6) Data in Table	Not Applicable	A-2, A-3	A-7, 7	5, 6, 7	9	14	11

Notes: 1) All changes measured against base freeboard draft large crude tanker of about equal DWT meeting IMCO outflow criteria.

2) As percent of Full Load Displacement.

3) Average value for long and short voyages for 0 tax case. See Tables 5 and 6 for actual values.

4) Range for two ballast displacements and two tank washing procedures. See Section V A for discussion.

5) Values are for "typical" stranding or collision. See Section V B.

SECTION I. INTRODUCTION

The Maritime Safety Committee, at its XXIII Session, recalling Resolution 1 of the 1954 Conference on the Prevention of Pollution of the Sea by Oil which called for "The complete avoidance as soon as practical of discharge of persistent oil into the sea", agreed that one of the main objectives of the 1973 Conference on Marine Pollution should be the achievement by 1975 if possible, but certainly by the end of the decade, the complete elimination of the willful and intentional pollution of the seas by oil and other noxious substances as well as minimization of accidental spills.

To that end, an accelerated work program was agreed upon by the scheduling of extra sessions of the Subcommittee on Ship Design and Equipment and the Subcommittee on Marine Pollution.

With reference to the work to be carried out by the 1973 IMCO Conference, with the view to achieving the complete elimination of the intentional discharges of oil, the United States submitted to the Subcommittee on Ship Design and Equipment a note (DE VII/2/4), containing an outline of five possible problem areas and alternative solutions in order to achieve complete elimination of intentional pollution of the sea from ships. The paper suggested that these five areas be studied in order to assess the economic, operating and design aspects of the potential solution. In relation to one of

these studies, the paper set out an outline of the Study for Segregated Ballast Tankers which was already being undertaken in the United States. The paper proposed that the Segregated Ballast Tanker Study by the United States include such factors as capital costs, operating costs, practical operating problems and degree of effectiveness regarding pollution abatement.

A similar note by the United States was considered at the X Session of the Subcommittee on Marine Pollution (OPX/2/5). After consideration of the United States note and proposals submitted by other delegations, the Subcommittee on Marine Pollution agreed that it should proceed with nine studies on the basis of the outline set out in OP X/9, Annex II. The study of the Segregated Ballast Tankers is listed as Study 1, with the United States as the lead country and Norway, Sweden and the United Kingdom as associate countries.

The primary objectives of the study are:

1. To evaluate the effect of design modifications on oil pollution abatement for a range of very large crude carriers; and

2. To determine practical arrangements (designs) for a family of tankers with various segregated ballast capabilities.

The study has been divided into four subdivisions:

- Estimate of capital costs;
- Estimate of operating costs;
- Degree of effectiveness regarding pollution abatement; and
- Assessment of practical factors.

A family of eight designs of 250,000 ton deadweight crude oil tankers forms the basis for the study. To provide indications of the effect of design variations on tankers with deadweight quite different from 250,000 tons, two other baseline tankers were selected at about 120,000 and 500,000 tons deadweight. A single alternative design was developed for both of these deadweights to indicate whether trends observed for the 250,000 ton ships were changed in any significant manner. The three basic designs are hereafter referred to as the 120 series, the 250 series and the 500 series.

In each series an existing design was selected as a basis for baseline dimensions and characteristics. The power level was held constant for all variations of a given deadweight and the specifications for the basic ship were modified only to the extent necessary to reflect changes required by the design changes to the configuration. Since draft is often the most severe limitation on tanker dimensions, the draft of all versions in each size group was kept the same as the baseline design. Increasing the amount of segregated ballast in excess of that normally carried by a large crude tanker resulted in excess freeboard. Excess freeboard would in all likelihood also result if deadweight were held constant instead of draft. Holding length and beam constant also, the depth was changed to provide the maximum cargo deadweight capacity with varying amounts of segregated ballast capacity and cargo at 38^{o} A.P.I. (Specific gravity of 0.8348.)

While the end result is a family of ships which is deemed sufficiently representative of actual designs for comparison purposes, they should not be considered optimums.

These twelve designs were developed to permit an estimate of the effect upon capital and operating costs of each of the following:

1. Influence of the amount of segregated ballast capacity
2. Influence of protective features such as:
    - double bottoms
    - double sides
    - complete double skin
    - alternate cargo and ballast wing tanks

SECTION II. DESIGN AND ENGINEERING SUMMARY

This section of the report provides an overview of all designs developed in the course of the study. Before describing each version individually the bases common to all designs will be given.

In addition to those dimensional limitations mentioned in the introduction, the following design goals were achieved on all designs:

1. Sufficient cubic capacity is provided to permit carriage of full deadweight on a 22,000 mile voyage with a cargo gravity of 38^{o} A.P.I.

2. All designs satisfy standard classification society section moduli requirements without significant additional steel.

3. For each series of deadweight the draft is held constant.

4. For each series of deadweight the power and speed are held constant.

5. All designs employ ABS higher strength steels types AH and DH to the maximum extent deemed practical in longitudinal material. Ordinary strength steel is used elsewhere.

6. All segregated ballast tanks receive a complete surface treatment and a coating of inorganic zinc.

7. All designs meet the hypothetical oil outflow requirements proposed by IMCO.

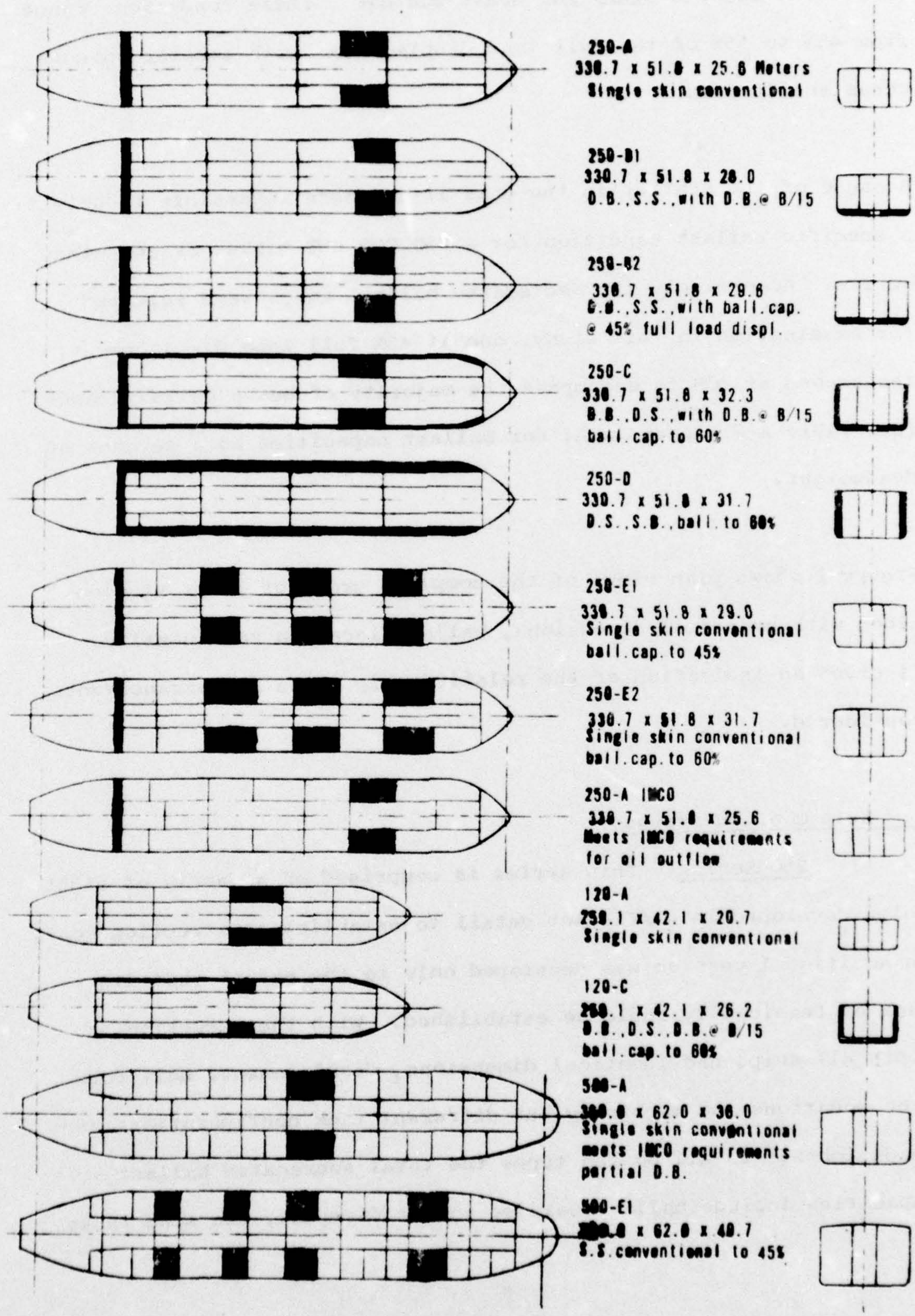
8. All designs possess sufficient stability to satisfy the damage requirements of the 1966 Loadline Convention.

9. The baseline designs in each series are freeboard draft designs; others are not.

Prior to determining the influence of the amount of ballast, the ballast requirements of each series had to be determined. The amount of ballast that will be carried on board a tanker is a function primarily of the ship's characteristics and of the weather conditions. The characteristics include bulbous bows, size, proportions and vibration and motion performance. But it is weather conditions which appear to have the most significant effect on the amount of ballast carried. In order to assess the frequency with which heavy weather is encountered in a typical large tanker trade route, log book data was reviewed.

These data indicated that heavy weather conditions (Beaufort 6 or greater) will be encountered in over 90% of the voyages between Northern Europe and the Persian Gulf, which is one of the most important large tanker routes today. Although the ballast carried in this trade showed a considerable amount of scatter, there appear to be several trends. One is that the amount of ballast carried, as a percentage of full load displacement decreases with increasing ship size. Secondly, there appears to be two basic conditions at which the large tankers operate, one for normal weather (Beaufort

Fig. 1 **SEGREGATED BALLAST TANKER STUDY-SHIP CONFIGURATIONS**



5 or less) and the other for heavy weather. These conditions range from 45% to 55% of the full load displacement with greater amounts occasionally used.

Because of the scatter in the data it has been impossible to select a specific ballast condition for a 250,000 DWT tanker or any other series. Accordingly two segregated ballast cases were selected for examination in this study, one at 45% full load displacement, the second at 60% to encompass the majority of heavy ballast cases. (See Table A-2, Appendix A, for ballast capacities as a percent of deadweight.)

Figure 1 shows plan views of the complete group of ships studied along with principal dimensions, ballast location and quantity. It gives an indication of the relative ship sizes and arrangements considered.

A. Ship Configurations

1. 250 Series: This series is comprised of a family of eight ships developed in sufficient detail to establish construction cost. An additional version was developed only to the extent that its lack of feasibility could be established. With the exception of depth all ships had identical dimensions, displacement, hull form, accommodations and machinery but different tank configurations and deadweights. In all design types the total segregated ballast capacities include ballast carried in the forepeak, the wing tanks,

and other miscellaneous tankage. The base ship, (a), is similar to an existing vessel.

(a) 250-A: This design is a single skin conventional ship of about 250,000 L.T. deadweight as shown in drawing No. 250A-1. It is typical of a large crude tanker now in operation.

(b) 250-A IMCO: This design represents one method of adjusting the design of 250-A to meet the IMCO oil outflow limitation of 30,000 cubic meters. It is shown in drawing No. 250-IMCO. This design constitutes the correct base for comparison of the remaining variations since all subsequent designs also meet the IMCO oil outflow limits.

(c) 250-B1: This design incorporates a B/15 double bottom depth with sufficient depth increase to maintain required cubic. It is shown in drawing No. 250B1-1.

(d) 250-B2: This design includes a double bottom of sufficient depth to provide a total ship segregated ballast displacement of 45% of full load displacement. It is shown in drawing No. 250B2-1.

(e) 250-C: This design includes a double bottom with a depth of B/15 plus a double side skin of sufficient width to provide segregated ballast capacity necessary for a segregated ballast displacement of 60% of full load displacement. It is shown in drawing No. 250C-1.

(f) 250-D: This design includes double sides of sufficient width to yield a segregated ballast displacement of 60% of full load displacement without a double bottom. It is shown in drawing No. 250D-1.

(g) 250-E1: This design represents a single skin conventional tanker with requisite depth increase needed to provide a segregated ballast displacement of 45% of full load displacement. The segregated ballast is carried in alternate wing tanks. It is shown in drawing No. 250E-1.

(h) 250-E2: This design has the same features as 250-E1, but provides sufficient ballast to enable a segregated ballast displacement of 60% of full load displacement. It is shown in drawing No. 250E2-1.

(i) 250-F: An end point design not shown in Fig. 1 was considered wherein both double bottoms and double skins were provided which met the IMCO damage assumptions, i.e. B/15 for bottom penetration and B/5 for side.

The provision of B/15 and B/5 double bottom and skins respectively requires that nearly 50% of the cross-section area be devoted to segregated ballast or void spaces. Retaining the design approach of only varying depth to regain cargo cubic capacity lost to ballast resulted in a design with an abnormal beam to depth ratio of 1.37. As a consequence, this design had deficient stability characteristics. The great depth needed to obtain the required cubic resulted in a cargo center of gravity so high there were only about 2 feet (0.61 m) of GM available in the full load departure condition. This compares to over 20 feet (6.1 m) normally found. The damage stability standards set by the Loadline Convention could not possibly be achieved. Efforts to improve the stability by increasing beam and

reducing depth indicated that reasonable stability did not occur unless the design length/beam ratio approached 5 which is lower than what is presently considered good practice. For this reason this version was dropped from further detailed consideration.

2. <u>120 Series</u>: Two ships form this series. With the exception of depth, both ships possess identical dimensions, displacement, hull form, accommodations and machinery but with different tank configurations and deadweights. The base ship (a) is similar to an existing vessel now under construction.

(a) 120-A: This design is a single skin conventional tanker of about 120,000 L.T. deadweight. It provides a base price for evaluating the effect of changes and is shown on drawing No. 120A-1.

(b) 120-C: This design includes a double side and double bottom with a depth of B/15. As on 250-C the segregated ballast displacement was maintained at 60% of full load. It is shown in drawing No. 120C-1.

3. <u>500 Series</u>: Two ships form this series. With the exception of depth, both ships possess identical dimensions, displacement, hull form, accommodations and machinery but differing tank configurations and deadweights. The base ship (a), is similar to a design presently under construction.

(a) 500-A: This design represents a nominal 500,000 DWT tanker. A 477,000 DWT ship was selected as a basis and modified to meet IMCO oil outflow requirements by increasing the subdivision

and including a double bottom in the number 2 centerline tank. It is shown in drawing No. 500A-1.

(b) 500-E1: This design is similar to 500-A with the exception of a segregated ballast capacity sufficient to provide a ballasted displacement of 45% of full load. The ballast is located in wing tanks placed intermittently along the ship side.

B. Design Procedure

This study has been conducted by a joint working group in consultation with the American Bureau of Shipping. To meet the target date for the Study Report to be considered at the VIII Session of the Sub-committee on Ship Design and Equipment, scheduled for June 12, 1972, the work effort in the area of cost estimating, and structural design and steel weight estimates was contracted out to a U. S. firm of naval architects.

The prime contractor, working together with the American Bureau of Shipping, completed the basic design studies required to determine the construction costs in a representative shipbuilding center (Japan) for each of the twelve crude oil tanker designs.

The preliminary design information was furnished to the contractor and the American Bureau of Shipping for each of the tanker configurations. Based on that information, general arrangement plans, skeleton midship sections, skeleton bulkhead scantling plans and cargo oil and ballast piping diagrammatic plans were developed by

the contractor. The American Bureau of Shipping reviewed the structural plans and found the scantlings acceptable for the purposes of this study.

Based upon information available from preceding studies it was decided that there were three major areas of cost differences. These areas were identified as follows:

1. Hull Steel
2. Tank Coatings
3. Cargo Oil and Ballast Systems

The designs were developed so that primary attention was devoted to these major areas of cost difference.

Consequently, in addition to midship sections and detailed bulkhead scantling determinations, diagrammatic cargo oil and ballast piping drawings were prepared and the total area on each design receiving special coatings was determined by means of tank by tank area calculations accounting for structure.

Steel weights were considered to be the single most important aspect of the cost differences and the following paragraphs outline the method used in obtaining this estimate. An accurate material take-off was made for each of the designs covering longitudinal and transverse material in the 0.4L amidships.

By analysis of the scantlings on a ship of similar dimensions, which had actually been built, the extent of the weight reduction for longitudinal material in the tank space outside the 0.4L amidships, due to the taper in the scantlings and the effect of hull form, was approximated. Likewise, the extent of the weight reduction of transverse material (bulkheads and web frames) in the tank space outside the 0.4L amidships, due to the effect of hull form, was determined.

Available scantling plans for the ship which was used as the basis for the 250-A design were studied in detail to determine the weight relationships between plating and stiffeners in the tank space outside the 0.4L amidships with corresponding members within the 0.4L. Area relationships were also developed for structural members which taper due to hull form.

Factors for the inner bottom were based on area relationships determined from the lines plan of the parent design for the 250 Series with inner bottom scantlings assumed to remain constant. Factors developed for the 250-A, 250-C and 250-E1 designs were used for the 120 and 500 Series.

The end weights used were based on the average weight per foot of depth of the hull previously selected for the conventional designs. Machinery weights were estimated for all designs and no major variations occurred as a result of any design changes. Outfit

weights were developed for the base ship in each series and weight differences due to increased depth, increased ballast piping, pumps, or cargo piping were considered as increments to the base ship.

C. Design Comparisons

Tables A-1 and A-2 in Appendix A summarize the principal characteristics of the twelve designs, provide information on the total deadweight capacity, cargo cubic capacity and ballast capacity. As stated earlier no dimensions within a given series varied with the exception of depth. For the 45% ballast designs depth increases of about 13% were necessary in all series. As segregated ballast was increased to the 60% condition depth increase doubled to about 26% deeper than the base case. The design basis requiring sufficient cargo cubic to carry the full deadweight of oil at 38^{o} A.P.I. gravity was achieved. The ballast to deadweight ratios fall within narrow bands depending on the required segregated ballast displacement. This finding was independent of deadweight series. The base ship ballast capacity ranged from 16 to 20 percent of the deadweight. Ships designed for 45% ballasted displacement had ratios about 40% with 56% being the resultant ratio for a 60% segregated ballast displacement. 250-B1 which was not designed for a specified ballast displacement possesses a ballast/deadweight ratio of 30% which is midway between the base cases and the 45% designs.

Table A-3 in Appendix A presents the weight summary developed for each design. Due to the time restriction imposed in preparing this study it was not possible to optimize the structure on each design and the resultant weights may not represent minimum weight designs. The steel weight to displacement ratio is about .11 for all three base ships. The highest ratios are for 120-C at .17 and 250-C at .15. The increases, in general, followed closely the variation in depth and structural complexity. The steel weight fraction of the total light ship weight ranges from .81 for 120-A to .88 for 500 El. The trend for this fraction increases with deadweight, and for a given deadweight increases slightly over the base ship as the ballast capacity increased or structural complexities such as double bottoms or double sides are added. Since depth was increased on all variations of the base ship it is not surprising to find that the percentage of ordinary strength steel also increases for all modifications of the base ship. The percentage increases range from 5% on 500-El to 32% on 120-C. For 250-C the percentage increase in ordinary strength steel was 29%. This trend can be explained by noting that the length/depth ratio of the 120-A and 250-A are 12.5 and 12.9 respectively, whereas this ratio on 500-A is 10.0. In general the lower the L/D ratio becomes the more efficiently longitudinal material can be used. Hence the variations of 120-A and 250-A resulted in deeper ships permitting greater application of ordinary strength steel.

The benefits due to increased depth are not without limit. For length/depth ratios less than 10.0 very little additional credit is permitted, hence, there is a rather small increase in the percentage of ordinary strength steel on design 500-E1. The percentage increase in ordinary steel grows at a faster rate than the percentage increase in depth when double bottoms are fitted but at a slower rate when no double bottoms are used.

The outfit weights for all designs fall in a narrow range between .08 and .11 of the total light ship weights with the lower values occurring on the deeper ships which experienced appreciable increases in steel weight.

The longitudinal strength studies performed for three load conditions showed that all designs in each series required the same section modulus. The highest bending moments are summarized in Table A-4 of Appendix A.

As a result of the stability problems encountered on the aborted version 250-F, the damage stability on selected other designs was examined. On the basis of the worst damage condition, namely damage to two adjacent wing or double bottom ballast tanks, if possible, and penetration to interior ballast tanks as on design 250-C, the base ship, 250-A, possesses the greatest margin of GM over that which is required. Although margins are less for the

deeper ships they all complied with the damage stability requirements of the Loadline Convention. Table A-5 in Appendix A summarizes the results of the stability calculations.

As noted in the design bases all designs were required to comply with the proposed IMCO oil outflow regulations. It was for this reason that a 250-A IMCO design was developed. The parent 250 did not meet the outflow requirements either for collision or stranding, but relatively minor modifications to the arrangement assured compliance. The outflows based on the IMCO criteria are presented and discussed in Section V. Design 250-E1 failed to meet the requirements. However, by moving the forward bulkhead of number 2 ballast tank forward two frame spaces, the number 3 centerline cargo tank bulkhead forward 3 frame spaces, and the forward bulkhead of number 3 ballast tank aft two frames, the outflow meets IMCO requirements. This approach does not change the number of tanks, the total ballast or the cargo capacity. Figure 2 shows the arrangement of the revised version which meets IMCO outflow. Since this rearrangement should result in little or no change in cost the economic studies are valid.

The areas which require special coating are provided in Table A-6 of Appendix A.

250-E1 - Alt. 1

CHANGES:

Wing tank bulkhead moved from 608.8' to 643.3' Aft. FP

Wing bulkhead moved from 401.58' to 367.06' Aft. FP

Bulkhead moved from 401.58' to 349.8' Aft. FP

Bulkhead at 280.86' Aft. FP deleted

Bulkhead added at 194.56' Aft. FP

REASON FOR MOVE:

O_s exceeded IMCO (was 32,673 m^3)

RESULTANT IMCO OUTFLOWS:

O_s = 29,518 m^3 (tanks 4c, 5c, 4w)

O_c = 21,290 m^3 (tank 3w)

EFFECT ON TRIM:

Condition	Old Trim	Alt. 1
Full	1.60' A	1.36'A
60% Ball	8.59' A	0.93'A
45% Ball	3.02' A	4.96'A

EFFECT ON STRENGTH: **BENEFICIAL**

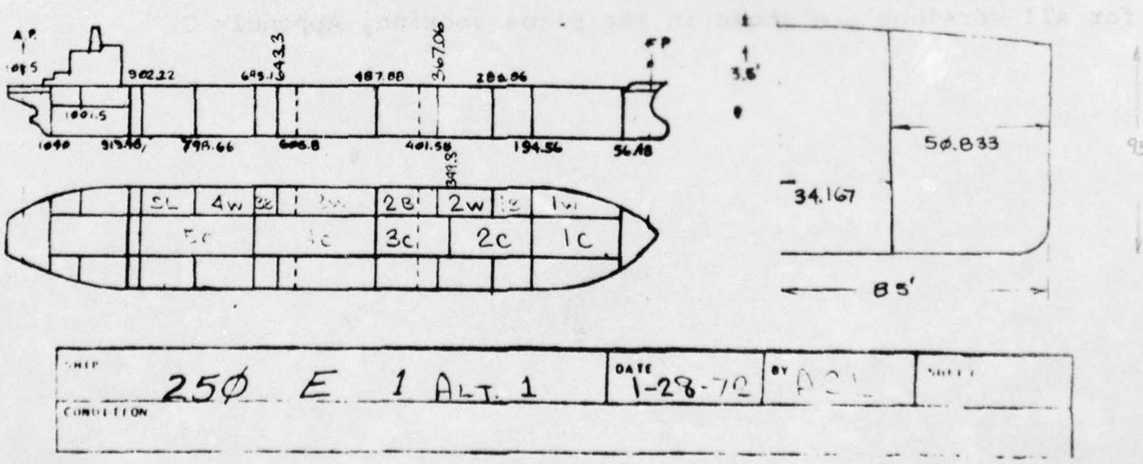


Fig. 2 Alterations To Design Type 250-E1

Changes to the base ship resulted in changes to the piping system. Increasing the number of tanks modified the piping system accordingly. Increases to the amount of segregated ballast carried required an increase in ballast piping and an increase in ballast pumping capacity. A duplicate pump and ballast mains were added for the ships with segregated ballast of 45% or more.

In the double bottom ship versions, in order to minimize the possibility of cargo oil leakage into the pipe tunnel, the piping was changed to welded steel without flanges and with expansion loops rather than flexible couplings. The double bottom designs permit a significant reduction in the number of bellmouths and piping due to the sumps common to double bottom designs.

No attempt was made to optimize piping on any single ship but simply retain systems developed for the actual designs which were intended to be quite flexible. The diagrammatic piping drawings for all versions are shown in the plans section, Appendix C.

SECTION III. CONSTRUCTION COST

A. General

Using data from Japanese sources as representative, the prices for each of the twelve designs as developed in this study were estimated. A summary of the ship prices and differentials is included in Table A-7 of Appendix A. These figures represent the shipyard selling prices.

The prices for ships which represent departures from conventional designs have been established on the basis of estimating the cost of differences in material and labor requirements and other direct and indirect costs. Estimating factors were used which make adjustments for added complications in construction practices as compared with the conventional designs. No additional price premium has been added to offset the resistance which might be encountered by an owner in attempting to contract for the construction of a complicated design at a time when shipyards expect that orders for conventional types may continue to be obtained in reasonable quantity.

The cost estimates are based on the premises that shipyard experience and facilities are adequate to build any of these designs, that pricing of all designs are suitably related to make a contract for any one of them equally attractive to the shipyard and that owners will no longer be restricted to only the conventional design but

may choose one or more of the unconventional designs for quantity orders in the future.

Although primary attention was devoted to the major areas of cost differences noted previously other items such as the ballast pump, anchors and chain, hatches, manholes and gratings, and vertical inclined ladders were compared and priced. Pricing of hull steel required a major effort in estimating steel weights and the details are given below. Tank coatings were priced on calculated areas. Due to the wide variations in arrangement and number of cargo oil and ballast tanks, piping system costs were based on detailed estimates using each of the diagrammatic plans.

B. Pricing of Hull Steel

Steel weights for each design were broken down into mild steel and higher strength steel (ABS 36). Longitudinal higher strength steel grades within the four tenths length amidship was assumed to be a 50/50 mixture of AH and DH grades. Longitudinal higher strength steel outside the four tenths length was assumed to be all of AH grade. All material forward of the forepeak bulkhead and aft of the machinery space bulkhead was assumed to be mild steel with a mixture of 60% plate material and 40% shapes. Unit prices per ton were determined for each of the materials involved as well as for welding rod. These were adjusted by a percentage factor to cover the shipyard scrap allowance and rolling tolerances.

Values of labor man hours per ton of mild steel for the conventional designs obtained from various sources within the representative shipbuilding country were found to be generally consistent. Guidance was obtained in determining the man hours required for higher strength steel construction and in establishing estimating factors for labor man hours for each of the design variations based on careful study of the individual configurations and the related construction complications. Current wage and charge rates were investigated as well as escalation values which might be anticipated for the 1974 delivery period.

An allowance was added to the total of the material and labor costs to cover general expense, management expense, profit, market allowance, etc., in order to give a selling price level which is representative of the current shipbuilding market situation.

C. Pricing of Other Differences

As noted above the added cost of special tank coatings were computed on an area basis as were the exterior paint requirements resulting from increased hull depth. Exterior paint areas were calculated by multiplying the added depth by the longitudinal girth of the hull at the deck level. The prices of cargo oil, ballast and stripping systems were based on detailed estimates using each of the diagrammatic plans by identifying material, quantity, size and weight of piping, valves and fittings. The piping systems were priced on a weight basis with unit prices applied to the net

weights of:

Piping and flanges

Valves

Fittings

Labor man hours were also calculated on a weight basis. Piping system price differences are entered in Table A-7.

Due to the amount of money involved, the prices of the additional ballast pumps required for certain of the designs have been entered as a separate item on Table A-7.

Other items of minor significance which were considered include the following:

1. Anchors and Chains - price differences based on weight differences.

2. Hatches, Manholes and Split Gratings - price differences based on detailed quantity take-offs.

3. Vertical and Inclined Ladders - price differences based on lengths.

These price differences are all summarized in Table A-7.

D. Price Comparison

Analysis of the price information provided in Table A-7 of Appendix A confirmed the early indication that the cost of steel, coatings and paint, and cargo oil stripping and ballast piping would be the

primary areas of price difference. In fact, with the exception of 250-A IMCO, steel and coating price differentials accounted for at least 85% of the total differential and usually over 90%. Even 250-A IMCO had 79% of its cost differential in these two categories. It was held at that lower value because of the relatively minor design changes consisting of additional transverse bulkheads which did not increase steel weight and cost at a rate greatly different from the increase in piping required for the additional tanks. Considering only those ships with increased segregated ballast capacity or some type of double skin, it can be seen that the steel cost increment alone is always more than 50% of the total increment and with the exception of 250-El exceeds 70% for all other cases. The reason why 250-El exhibited a lower steel cost increment can be attributed to the following:

1. The length/depth ratio was high enough that more efficient use of steel was possible with a depth increase, thereby permitting greater use of ordinary strength steel.

2. The tank arrangement and number remained relatively low resulting in smaller increases in transverse steel structure than on other designs.

3. At the same time steel cost increments were limited, coating and piping costs were rising at a more rapid rate due to increased ballast capacity.

In contrast to a 4.2% cost increase for 250-E1, 500-E1 exhibited a 9% increase in construction cost. This can be attributed to the proportions of the base 500 design previously mentioned, which did not lend themselves to improved structural efficiency when depth was increased. In fact there was little reduction in the total amount of high strength steel used and an 18% increase in total steel compared to less than 7% on 250-E1.

Attempts to draw conclusions based on small differences in incremental costs should be done with caution. This is due to the fact, mentioned earlier, that none of the designs have been optimized with regard to structural design or any other area of cost difference. Thus one version may be a very good design compared to another although both are feasible and useful for general comparisons.

For the 250 series ships which were modified, excepting 250-A IMCO, incremental coating costs ranged from 11% to 31% of the total cost differential.

The importance of cargo oil stripping and ballast piping changes was variable. Due to the elimination of numerous bellmouths and general simplification of piping arrangement in the double bottom designs, there was little cost change due to double bottoms. 250-B1 actually resulted in a cost decrease even though welded piping with expansion loops was required. Increases in the number of tanks and total ballast capacity had a more significant effect

on price change, but still considerably less significant than tank coatings which were several times less important than steel.

All the other items combined represented less than 5% of the total cost differential for each design. This confirmed the validity of the decision to concentrate efforts on steel, coatings and piping systems.

SECTION IV ECONOMIC ANALYSIS

A. Basic Approach

Economic analyses have been made for each of the ship designs to show the relative effect of the basic design changes on the marine transportation costs. Possible shore cost differentials have not been considered. The measure of marine transportation costs used is the required freight rate (RFR) which accounts for amortization of capital as well as operating costs.

RFR values have been calculated for two voyage lengths:

- A long voyage of 22,000 n.m. round trip is taken as typical of the longest normal crude tanker voyages.
- A short voyage of 5,000 n.m. round trip has been taken as typical of the shortest voyages normally made by large crude carriers.

The calculations reflect typical cost parameters which may be expected during the 1970's under non-U. S. conditions. Since they do not reflect a specific flag, trade, or date, however, these results should be viewed principally in relation to each other rather than as absolute values. Sufficient information is presented, however, so that calculations for variations in individual parameters may be made.

B. Base Ship Economics

The principal economic bases are given in Table 1, and principal operating parameters are given in Table 2. Table 3 shows a percent

breakdown of economics for each of the three base case ships (120-A, 250-A IMCO, 500-A), each in a long and short voyage in a zero tax environment while Table 4 presents similar data with a 50% tax. Further details of the economic analysis are provided in Appendix B.

These relative economics for the base case ships have been presented prior to a discussion of the economics of design changes under study in order that the basic makeup of large tanker economics may be properly understood. This understanding may be further facilitated by taking note that for both long and short voyages the various parameters show the following trends.

- Capital costs are the largest component of RFR being in the range of 46 to 58% with no tax, and 57 to 68% with 50% tax.
- Insurance and fuel costs, as well as port charges in the short voyage, are next most important.
- Components having a lesser impact on RFR are manning, provision/stores, repairs, and miscellaneous.
- All large tankers have a high number of operating days per year, a very high percentage of which are spent at sea.

As noted in Section II of this paper, the three base ships (120-A, 250 IMCO, and 500-A) are not a part of a common series or common specification base and therefore comparisons should not be made from these data in regard to the trend of economies with scale.

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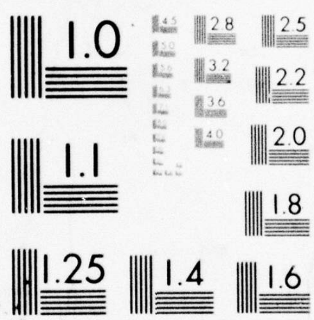

MICROCOPY RESOLUTION TEST CHART
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TABLE 1 Principal Economic Bases

Cost of Capital	10%
Ship Life	20 years
Scrap Value	10%
Tax Rate	0% and 50% (for 50% tax rate, double declining balance depreciation is used)
Crew Cost	$350,000 per year
Provisions and Stores	$150,000 per year - 120 series
	$175,000 per year - 250 series
	$225,000 per year - 500 series
Fuel Price	$23 per ton
Maintenance & Repair	$200,000 per year - 120 series
	$250,000 per year - 250 series
	$300,000 per year - 500 series
Insurance and Port Charges	See Appendix B

TABLE 2 Principal Operating Bases

	LONG VOYAGE			SHORT VOYAGE		
	120 A	250 IMCO	500 A	120 A	250 IMCO	500 A
Round Trip (n.m.)	22,000	22,000	22,000	5,000	5,000	5,000
Sea Speed (kt.)	16.24	15.95	14.60	16.24	15.95	14.60
Sea Days	56.4	57.3	62.8	12.8	13.1	14.3
Port Days	3.0	3.0	3.0	3.0	3.0	3.0
Days/trip	59.4	60.3	65.8	15.8	16.1	17.3
Oper. Days/yr.	350	350	350	350	350	350
Trips/yr.	5.89	5.80	5.32	22.15	21.74	20.23
Cargo Deadweight (LT)	116,319	239,285	460,327	121,544	246,572	467,563
Cargo Delivered/yr. (LT)	685,120	1,387,855	2,448,940	2,692,209	5,360,483	9,458,800
Dry Dock Cycle	18 months	18 months	18 months	18 months	18 months	18 months

TABLE 3 Breakdown of Base Ship Economics - Zero Tax

	22,000 MILES R/T			5,000 MILES R/T		
	120 A	250 IMCO	500 A	120 A	250 IMCO	500 A
Annual Costs as % of Total						
Amortization	49%	56%	58%	46%	51%	52%
Insurance	10%	15%	18%	10%	13%	17%
Fuel Cost	21%	15%	12%	18%	12%	10%
Port Charges	3%	4%	4%	11%	14%	14%
Manning	8%	5%	3%	7%	4%	3%
Repairs	4%	3%	2%	4%	3%	2%
Prov/Stores	3%	2%	2%	3%	2%	2%
Miscellaneous	<1%	<1%	<1%	<1%	<1%	<1%
TOTAL	100%	100%	100%	100%	100%	100%

TABLE 4 Breakdown of Base Ship Economics - 50% Tax

	22,000 MILES R/T			5,000 MILES R/T		
	120 A	250 IMCO	500 A	120 A	250 IMCO	500 A
Annual Cost as % of Total						
Amortization	60%	66%	68%	57%	61%	63%
Insurance	8%	11%	14%	8%	10%	13%
Fuel Cost	17%	11%	9%	15%	10%	8%
Port Charges	2%	3%	3%	9%	11%	11%
Manning	6%	4%	2%	6%	3%	2%
Repairs	4%	3%	2%	3%	2%	2%
Prov/Stores	3%	2%	1%	3%	2%	1%
Miscellaneous	<1%	<1%	<1%	<1%	<1%	<1%
TOTAL	100%	100%	100%	100%	100%	100%

C. Economic Results

Table 5 presents details of the RFR values for all 12 cases for the long voyage and Table 6 presents similar data for the short voyage. RFR's are shown both for the zero and 50% tax assumptions. Before examining these results by parts the net change in RFR values for each ship design variation against its respective base vessel is shown in Table 7.

From Table 7 the following trends should be noted:

- The percent change in RFR for each design variation may be approximated reasonably closely by knowing the percentage change in investment.
- The percent change in RFR for any particular design feature is not strongly influenced by voyage length.
- The percent change in RFR for a particular type of design feature should not be strongly influenced by tanker size in the large crude tanker range. For example, compare the percent change for 120-C with that for 250-C. The case of 500-E1 versus 250-E1 appears to be somewhat distorted by the large increase in capital cost for 500-E1 over 500-A. As discussed previously, this has been caused by the unusual proportions of these two ships.

Despite the higher influence of investment on RFR, other components of RFR will also be influenced by ship design changes as can be seen from Tables 5 and 6. While a detailed discussion of the impact

TABLE 5 Required Freight Rate - Long Voyage (120 and 500MDWT Cases)

	120-A	120-C	500-A	500-E1
Construction Cost (MM$)	20.1	24.7	65.0	70.8
Annual Costs (M$)				
Operating -				
Insurance	463.3	463.7	2295.1	2282.1
Fuel	961.8	961.9	1513.2	1513.1
Port Charges	141.3	179.0	521.6	590.0
Manning	350.0	348.2	350.0	347.2
Repairs	200.0	209.3	300.0	321.4
Prov/Stores	150.0	150.0	225.0	225.0
Miscellaneous	15.0	15.0	40.0	40.0
Total Oper. Costs	2281.3	2327.1	5244.9	5318.7
Amortization - 0 Tax	2217.0	2724.4	7169.5	7809.2
Amortization - 50 Tax	3390.9	4166.9	10965.5	11944.0
Total Annual Cost - 0 Tax	4498.3	5051.5	12414.4	13128.0
Total Annual Cost - 50 Tax	5672.2	6494.0	16210.4	17262.7
Deadweight (LT)	124,379	116,383	474,062	463,264
Cargo Delivered/yr. (LT)	685,120	638,766	2,448,940	2,391,155
RFR - 0 Tax ($/LT)	6.57	7.90	5.07	5.49
RFR - 50 Tax ($/LT)	8.28	10.17	6.62	7.22
% Increase RFR - 0 Tax	-	20.4	-	8.3
% Increase RFR - 50 Tax	-	22.8	-	9.1

TABLE 5 (continued) Required Freight Rate - Long Voyage (250MDWT Case)

	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
Construction Costs (MM$)	37.7	37.4	40.1	41.0	44.3	41.8	39.3	41.4
Annual Costs (M$)								
Operating -								
Insurance	1079.4	1078.9	1076.9	1078.5	1079.0	1077.5	1081.1	1076.5
Fuel	1099.0	1099.0	1099.5	1099.3	1098.9	1098.3	1098.7	1098.4
Port Charges	295.4	295.4	324.6	342.0	373.0	365.0	334.0	365.0
Manning	350.0	350.0	349.0	348.3	347.7	348.5	349.0	348.5
Repairs	255.3	250.0	257.5	264.9	273.9	276.5	265.7	271.9
Prov/Stores	175.0	175.0	175.0	175.0	175.0	175.0	175.0	175.0
Miscellaneous	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Total Oper. Costs	3279.1	3273.2	3307.5	3333.0	3372.5	3365.8	3328.6	3360.3
Amortization - 0 Tax	4158.0	4125.0	4423.0	4522.0	4886.0	4598.0	4335.0	4566.0
Amortization - 50 Tax	6360.0	6309.4	6764.9	6916.7	7473.4	7051.7	6629.9	6984.2
Total Annual Cost - 0 Tax	7437.1	7398.2	7730.5	7855.0	8258.5	7963.8	7663.6	7926.3
Total Annual Cost - 50 Tax	9639.1	9582.6	10072.4	10249.7	10845.9	10417.5	9958.5	10344.5
Deadweight (LT)	248,990	249,360	244,216	243,070	237,508	241,288	246,711	241,876
Cargo Delivered/yr. (LT)	1,387,855	1,389,996	1,362,076	1,355,210	1,322,779	1,342,856	1,374,443	1,346,256
RFR - 0 Tax ($/LT)	5.36	5.32	5.68	5.80	6.24	5.93	5.58	5.89
RFR - 50 Tax ($/LT)	6.95	6.89	7.39	7.56	8.20	7.76	7.25	7.68
% Increase RFR - 0 Tax	-	-0.7	6.0	8.2	16.5	10.7	4.1	9.9
% Increase RFR - 50 Tax	-	-0.7	6.3	8.9	18.1	11.7	4.3	10.6

TABLE 6 Required Freight Rate - Short Voyage (120 and 500MDWT Cases)

	120-A	120-C	500-A	500-E1
Construction Cost (MM$)	20.1	24.7	65.0	70.8
Annual Costs (M$)				
Operating -				
Insurance	463.3	463.7	2295.1	2282.1
Fuel	871.5	871.6	1394.0	1393.4
Port Charges	530.7	672.0	1974.3	2245.0
Manning	350.0	343.7	350.0	342.6
Repairs	200.0	209.3	300.0	321.4
Prov/Stores	150.0	150.0	225.0	225.0
Miscellaneous	15.0	15.0	40.0	40.0
Total Oper. Costs	2580.4	2725.3	6578.4	6849.5
Amortization - 0 Tax	2217.0	2724.4	7169.5	7809.2
Amortization - 50 Tax	3390.9	4166.9	10,965.5	11,944.0
Total Annual Cost - 0 Tax	4797.4	5449.7	13,747.9	14,658.7
Total Annual Cost - 50 Tax	5988.3	6892.2	17,543.9	18,793.5
Deadweight (LT)	124,379	116,383	474,062	463,264
Cargo Delivered/yr. (LT)	2,692,209	2,525,271	9,458,800	9,236,120
RFR - 0 Tax ($/LT)	1.78	2.16	1.45	1.59
RFR - 50 Tax ($/LT)	2.22	2.73	1.86	2.03
% Increase RFR - 0 Tax	-	21.1	-	9.2
% Increase RFR - 50 Tax	-	22.7	-	9.7

TABLE 6 (continued) Required Freight Rate - Short Voyage (250MDWT Case)

	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
Construction Costs (MM$)	37.7	37.4	40.1	41.0	44.3	41.8	39.3	41.4
Annual Costs (M$)								
Operating -								
Insurance	1079.4	1078.9	1076.9	1078.5	1079.0	1077.5	1081.1	1076.5
Fuel	1016.0	1016.0	1018.0	1017.0	1016.0	1014.0	1015.0	1014.0
Port Charges	1112.0	1112.0	1226.8	1290.0	1409.0	1374.0	1257.0	1374.0
Manning	350.0	350.0	346.6	343.7	341.8	344.5	346.2	344.6
Repairs	255.3	250.0	257.5	264.9	273.9	276.5	265.7	271.9
Prov/Stores	175.0	175.0	175.0	175.0	175.0	175.0	175.0	175.0
Miscellaneous	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Total Oper. Costs	4012.7	4006.9	4125.8	4194.1	4319.7	4286.5	4165.1	4281.0
Amortization - 0 Tax	4158.0	4125.0	4423.0	4522.0	4886.0	4598.0	4335.0	4566.0
Amortization - 50 Tax	6360.0	6309.4	6764.9	6916.7	7473.4	7051.7	6629.9	6984.2
Total Annual Cost - 0 Tax	8170.7	8131.9	8548.8	8716.1	9205.7	8884.5	8500.1	8847.0
Total Annual Cost - 50 Tax	10,372.7	10,316.3	10,890.7	11,110.8	11,793.1	11,338.2	10,795.0	11,265.2
Deadweight (LT)	248,990	249,360	244,216	243,070	237,508	241,288	246,711	241,876
Cargo Delivered/yr. (LT)	5,360,483	5,368,540	5,282,696	5,254,587	5,129,721	5,186,290	5,307,541	5,199,078
RFR - 0 Tax ($/LT)	1.52	1.51	1.62	1.66	1.79	1.71	1.60	1.70
RFR - 50 Tax ($/LT)	1.94	1.92	2.06	2.11	2.30	2.19	2.03	2.17
% Increase RFR - 0 Tax	-	-0.6	6.2	8.8	17.8	12.4	5.1	11.6
% Increase RFR - 50 Tax	-	-0.7	6.5	9.3	18.8	13.0	5.1	12.0

TABLE 7 Percent Change In Required Freight Rate For Design Changes - Zero Tax

	% Increase in Investment	% Increase in RFR Long Voyage	% Increase in RFR Short Voyage
120MDWT Series			
1) Increase Segregated Ballast capacity to 60%, add Double Skin (Base to 120-C)	22.9	20.4	21.1
250MDWT Series			
1) Increase Segregated Ballast capacity to 45% (Base to 250-B1)	4.2	4.1	5.1
2) Increase Segregated Ballast capacity to 60% (Base to 250-B2)	9.8	9.9	11.6
3) Increase Segregated Ballast capacity to 40%, add Double Bottom (Base to 250-B1)	6.4	5.9	6.2
4) Increase Segregated Ballast capacity to 45%, add Double Bottom (Base to 250-B2)	8.7	8.2	8.8
5) Increase Segregated Ballast capacity to 60%, Add Double Sides (Base to 250-D)	10.9	10.7	12.4
6) Increase Segregated Ballast capacity to 60%, Add Double Skin (Base to 250-C)	17.5	16.5	17.8
500MDWT Series			
1) Increase Segregated Ballast capacity to 45% (Base to 500-B1)	9.0	8.3	9.2

of design features upon both operations and pollution considerations is contained in Section V of this report, the importance of these factors to the economics in Tables 5 and 6 is as shown in Appendix B.

D. Sensitivities

In order to investigate the importance of various economic and operating factors to the principal economic results just presented, sensitivity calculations have been made giving results as indicated below:

- Construction Cost

  For an assumed increase or decrease in investment differential between the case under study and its respective base case of ± 25%, the change in RFR will be as indicated in Table 8. As would be expected the percent RFR value changes almost directly in proportion to the change in investment differential for each case.

- Deadweight Differential

  For a ± 25% change in the deadweight differential between case 250-C and base (11,482 tons which is the largest deadweight differential) the percent RFR change is only 3.24%. From this example it can be seen that the estimated deadweight differentials are not highly significant to the percent RFR values.

TABLE 8 Sensitivity of RFR Differential To Investment Differential - Long Voyage, Zero Tax

	RFR DIFFERENTIAL (%)		
	For Original Invest. Diff.	For Original Invest. Diff. -25%	For Original Invest. Diff. +25%
120MDWT			
Base to 120-C	20.3	18.0	22.7
250MDWT			
Base to 250-B1	5.9	5.1	6.7
Base to 250-B2	8.2	7.0	9.4
Base to 250-C	16.5	14.8	18.2
Base to 250-D	10.7	9.1	12.3
Base to 250-E1	4.1	3.5	4.7
Base to 250-E2	9.9	6.1	13.7
500MDWT			
Base to 500-E2	8.3	5.1	11.5

- Port Days

If the turn around time of any design change compared to base is changed by four hours rather than two hours the percent reduction in RFR is only -0.2% in the long voyage, and -0.6% in the short voyage (example 250-B2 vs. 250-A IMCO). It should be apparent that it would take an exceedingly short voyage for this to be a factor of particular economic significance. Were this frequently to be the case, then sound economic grounds would exist for decreasing this port turn around differential in any case so that the basic RFR values are relatively insensitive to this factor.

- Operating Days

For a change of $\pm$ 3 days per year in operating days between any given case and its base (a 0.9% change) the percent change in RFR will be $\pm$ 0.6% (example 250-C vs. 250-A IMCO). It will be seen that this is an economic factor of some significance but it must be also assumed that means could be found to minimize the difference in operating days between the various tanker types. An exception to this could be the case wherein single bottom tankers in certain trades may require two to three days longer than double bottom tankers for sludge removal prior to drydocking, every 18 to 24 months. In trades where single bottom tankers incur this penalty it might be on the order of $1\frac{1}{2}$ days per year on average and change the RFR values by about 0.3%.

- Manning, Provisions/Stores and Repairs

  A change to any one of these parameters compared to base of ± 25% will only change the percent RFR over base by ± 1.1%. It can be seen that these estimates are not crucial to the principal findings.

- Insurance

  A ± 25% change in level of insurance for all cases would result in a ± 1.2% change to the RFR differential between 250-C vs. 250-A IMCO. This example shows that while insurance is a significant economic parameter its actual level is not crucial to the principal results. However, if the assumed method of assessing insurance is changed to reflect direct proportionality to capital investment (for reasons explained in Appendix B), it would have a significant effect on the RFR. For example, the effect on the largest RFR differential (250-C vs. 250-A IMCO) would be 15%.

- Fuel Cost

  A ± 50% change of unit cost of fuel will have a ± 3.7% effect on the largest RFR differential (250-C vs. 250-A IMCO). This shows that the level of fuel cost while important to overall economics is not significant to the principal results.

• Port Charges

A ± 50% change in the level of port charges in the short voyage will only have a ± 11.1% change on the RFR difference between 250-C and 250-A IMCO indicating that port charges are not significant to the principal results.

• Tax

As already shown, the effect of tax level, while significant to absolute values of RFR, has almost no effect upon the principal results of RFR differentials.

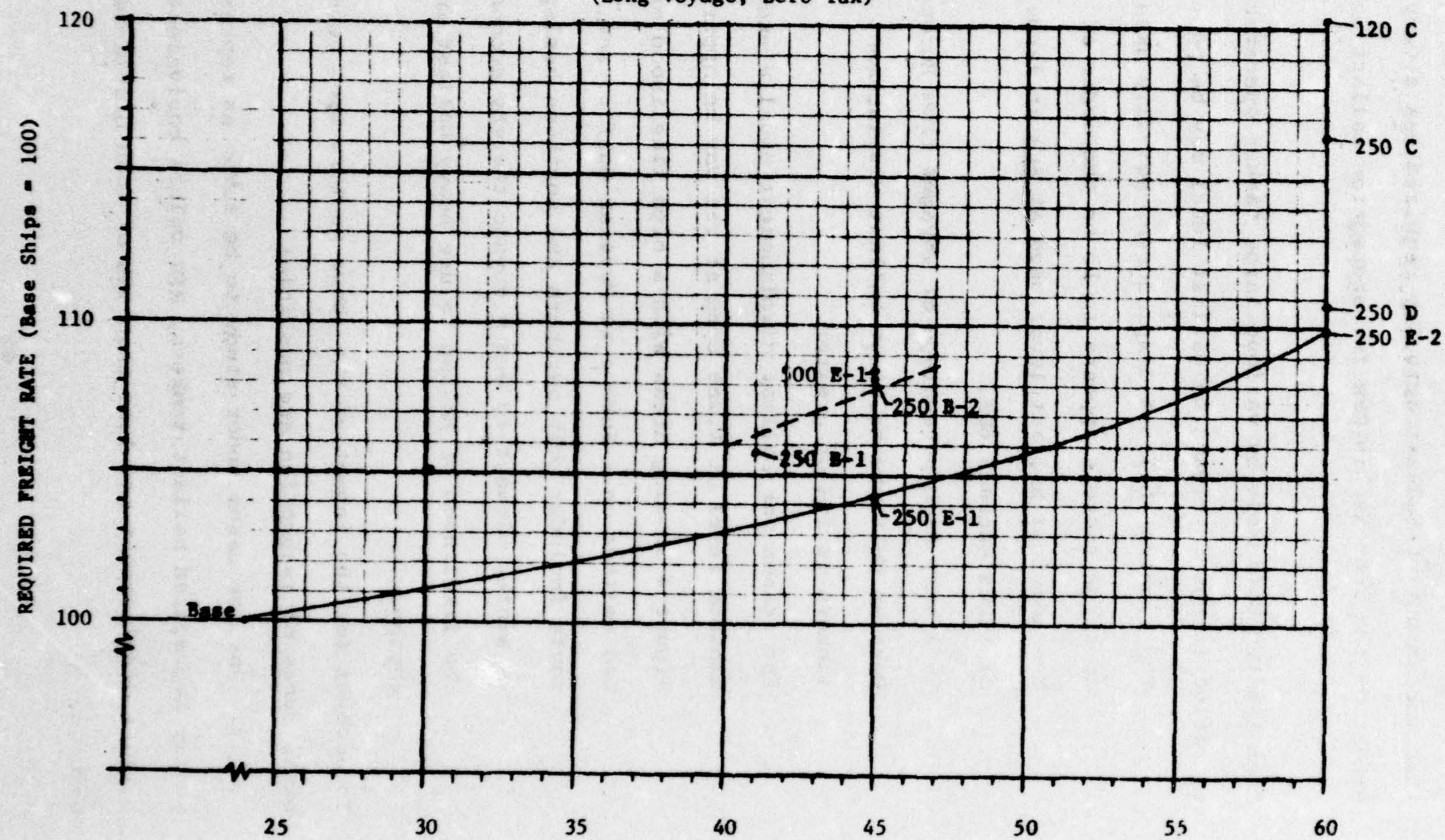
E. Economics of Ballast Level

Under the discussion of technical data in Section II it was noted that the study has several cases of similar ship types but at differing ballast levels in a range covering segregated ballast capability for ballast displacement at either 45 or 60% of the full load displacement. It was further noted that this range was selected since the amount of ballast actually needed throughout an entire ballast voyage will vary according to many parameters having principally to do with the severity of weather which the tanker may encounter.

In order to understand the influence of minimum necessary ballast for an entire ballasted leg upon marine transportation cost, the RFR values for the long voyage for all cases have been plotted in Figure 3, as a function of ballast displacement.

REQUIRED FREIGHT RATE
vs.
SEGREGATED BALLAST CAPACITY

(Long Voyage, Zero Tax)



% SEGREGATED BALLAST CAPACITY
Fig. 3

It is apparent from a comparison of 250-A IMCO, 250-E1 and 250-E2 that the amount of ballast actually required has a very significant effect on the increase in RFR for segregated ballast designs.

From limited data kept by various large tanker operators the following tentative trends in regard to ballast level may be postulated:

- The lightest ballast displacement actually used at sea in large tankers appears to be on the order of 45%.
- The heaviest ballast level used at sea in large tankers at times exceeds 60%.
- In a very high percentage of voyages from Europe to the Persian Gulf the heaviest ballast displacement in large tankers is 55% or greater.
- The reason for ballast displacement usually exceeding the minimum level at times used at sea may be apparent from Figure 4 showing areas with a high likelihood of encountering bad weather on a Europe to Persian Gulf voyage. Since this route includes both northern and southern hemispheres there is winter element to every voyage thereby accounting for the likelihood of having to use heavy ballast in every voyage.

To account for the impact of the above factors upon economics two basic types of assumption are possible:

1. For the cases under study to be taken as representative of wholly segregated ballast tankers, RFR values equivalent to a ballast displacement not less than 55% of load displacement should be used.

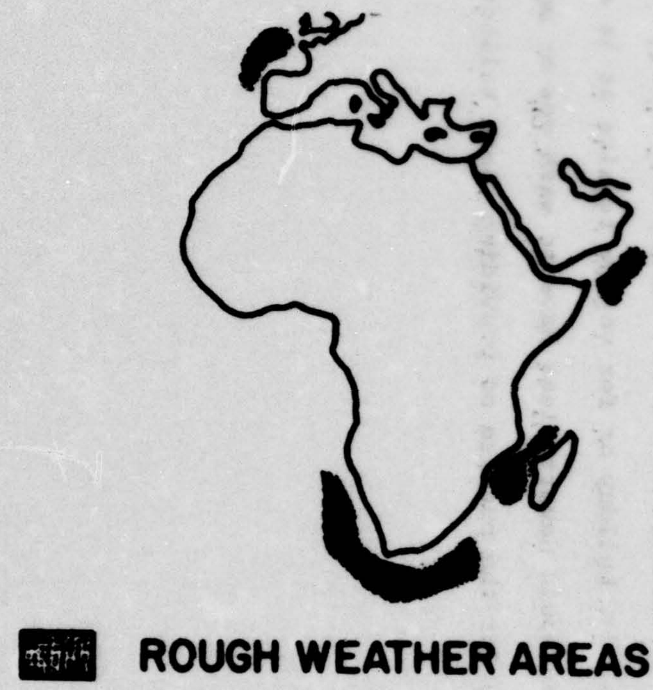


Fig. 4 Areas of Rough Weather - Persian Gulf to Northern Europe

2. Alternatively, and particularly for large tankers which may trade in shorter voyages or areas of primarily good weather, an RFR value appropriate to a ballast displacement 45% of full load might be selected. In this case if the vessel were to need additional ballast because of weather it may be assumed that this ballast can be placed in one of the tanks routinely cleaned to avoid sludge buildup and therefore be acceptable for discharge at the loading port. If operating experience indicates that large tankers with double bottoms do not need to wash cargo only tanks to prevent sludge buildup or for voyage repairs as is assumed in this study, they would nevertheless have to wash one or more tanks specifically for the purpose of providing clean ballast capacity.

SECTION V. DEGREE OF EFFECTIVENESS FOR POLLUTION ABATEMENT

Under this category, each of the design changes must be studied from two principal points of view:

1. Pollution effectiveness for operational discharges.
2. Pollution effectiveness for accidental discharges.

Subsections A and B below consider these two areas on an individual ship basis. Subsection C presents a possible methodology for combining both factors on the basis of total number of ships.

A. Pollution Effectiveness For Operational Discharges

Considering the mitigation of operational pollution, ships of the type studied here should show an improvement over base case ships for two principal reasons:

- In a ship with sufficient segregated ballast capacity to permit operation in ballast condition with segregated ballast only in all weather conditions there would no longer be any need to carry ballast in tanks that had previously contained oil. This would eliminate two sources of pollution which now exist for the base ships. First, it would no longer be necessary to place ballast in uncleaned cargo tanks to permit departure from the cargo discharge port. Second, it would no longer be necessary to wash cargo tanks to hold ballast which is clean enough to be discharged in the cargo loading port. Ships such as the 45% segregated ballast cases investigated

in this study will still almost certainly, on occasion, have to load ballast in cargo tanks to achieve an acceptable ballast operation condition. For these ships, pollution from these two sources will be reduced, but not eliminated.

- Those features of each design which decrease the amount of tank washing should also cause a reduction in operational pollution. In this regard, however, even with segregated ballast tankers, it will periodically be necessary to clean those tanks that are used to carry only cargo in order to remove sludge buildup and to prepare the vessel for drydocking inspection and repairs. It has been further assumed that in designs where the presence of a double bottom yields a smooth tank bottom, the sludge buildup will be effectively mitigated so that the need to wash tanks occurs only when the vessel is being prepared for her drydocking and overhaul period. This assumption places the double bottom in a favorable position as compared to the single bottom with regards to operational pollution. Further operating data for large tankers with double bottoms are needed to establish the validity of this assumption.

Operational discharge for the base case ships is being investigated in detail by the United Kingdom in Study No. III. However, for the purposes of this study, operational discharge for the base case

ships and all others, has been estimated using the following assumptions (for the first two items mean values are used in calculations for Table 9):

- Dirty ballast water contains 30-100 ppm of oil.
- Sludge tank effluent contains 300-1000 ppm of oil.
- Oil content in ballast water from cargo tanks that have been washed is less than 10 ppm.
- In discharging dirty ballast, 90% goes directly overboard at 30-100 ppm. The remaining 10% is sent to the sludge tanks for decanting.

For operational discharges from tank cleaning operations, two possible cleaning methods have been considered:

1. The cleaning is accomplished without recycling the wash water and without high capacity tank cleaning machines.
2. The cleaning is accomplished with recycled wash water and with high capacity machines. (Operational discharge will be reduced from case 1 because the amount of wash water is reduced.)

Single bottom and double bottom ships must be considered separately. All single bottom ships are assumed to have to wash each tank every fourth voyage to prevent excess sludge buildup. On the other hand, double bottom ships are assumed to clean tanks for sludge buildup only once every eighteen months. Also, because of the ease in cleaning a smooth bottom tank the amount of wash water in the non-recycling cases is assumed to be reduced by 2/3 for the double

bottom ships. The validity of both of these assumptions must be evaluated as further data become available.

Estimates using these bases are presented in Table 9 showing operational discharges per voyage for each design in cubic meters at two ballast displacement levels.

The following points should be noted:

- At 45% ballast displacement, the base ships (120-A, 250-A IMCO, 500-A) should be able to meet the requirement that maximum operational discharge per voyage be less than 1/15000 of deadweight using tank cleaning method No. 1 which represents the procedure now typical of the Load-On-Top method. At 60% ballast displacement, the discharge from the base ships is just over the 1/15000 requirement. If Study III indicates that the base ships can significantly improve on the data presented here, the relative significance of the various design features considered in this report would be directly reduced. Conversely, if Study III indicates poorer performance for the base ships the value of these features is increased. It should be noted that for even the base case ship a significant reduction in operational pollution should result from use of the improved procedures represented by tank cleaning method 2. Obviously, these techniques are also applicable to the other designs under consideration for tank cleaning.

TABLE 9 Operational Discharge Per Voyage

Ballast Loading / Tank Cleaning Method		45%		60%	
		1	2	1	2
Ship Type	DWT/15,000 *				
120 A	9.6	8.57	4.85	10.79	7.09
120 C	9.6	0.41	0.10	0.41	0.10
250 A	20.0	17.85	10.11	22.48	14.77
250 A (IMCO)	20.0	18.48	9.45	24.40	14.73
250 B-1	20.0	5.17	3.34	9.17	6.96
250 B-2	20.0	0.86	0.21	8.27	6.10
250 C	20.0	0.86	0.21	0.86	0.21
250 D	20.0	5.80	1.93	5.80	1.93
250 E-1	20.0	5.80	1.93	12.52	6.07
250 E-2	20.0	5.80	1.93	5.80	1.93
500 A	38.0	35.70	20.22	44.96	29.54
500 E-1	38.0	11.60	3.86	26.34	12.14

*Dwt/15,000 in m^3 for 38° API.

Notes: 1. All amounts in m^3, assuming 38° API cargo.

2. Description of tank cleaning methods
   1. Non-recycling of washwater, using conventional portable machines
   2. Recycling of wash water, using high capacity washing machines

- Increasing the amount of segregated ballast capacity, without a double bottom, should contribute significantly to reducing operational pollution. Depending on ballast level this reduction is estimated to be on the order of 50 to 75% (compare cases 250-D, E1, E2 to 250-A IMCO). This occurs since the need to put ballast in empty cargo tanks is reduced (or eliminated if sufficient segregated ballast is available). Accordingly, both tank cleaning and amounts of dirty ballast that must be handled would be reduced (or eliminated).

- The addition of a double bottom and segregated ballast should contribute a further reduction to operational pollution (compare case 250-B2 to 250-E1, and case 250-C to 250-D and E2). This occurs for two reasons. First, as discussed above, the need to clean cargo tanks to prevent sludge buildup may be eliminated. Second, in those cases when it is necessary to clean cargo tanks (for changing cargo grade, or to achieve a certain ballast displacement in ships that have only partial segregated ballast capacity, for example), the amount of wash water (in the non-recycling cases only) is reduced. The cumulative result of these two effects is estimated as a reduction of between 30 and 90% depending on the type of tank cleaning.

- Addition of double sides is not thought to contribute significantly to reducing operational pollution. A double side ship (without double bottom) should incur the same sludge buildup as any other single bottom ship. Also, while smooth sides might be somewhat easier to clean than the base ship, this credit would be less significant than that of the smooth double bottom.

The above are believed to be the principal directional findings which can be drawn from Table 9 in regard to operational pollution.

In making any further comparisons, it is important that the effect of changing segregated ballast level be considered separately from the impact of the other design features such as double bottoms and double sides. For example, in a direct comparison of 250-E1 to 250-C the relative effect of increased segregated ballast cannot be separated from the effect of adding a double skin. However, a comparison of 250-E1 to 250-E2 and then of 250-E2 to 250-C does permit a proper evaluation.

B. Pollution Effectiveness For Accidental Discharges

1. Introduction

This section will consider only those categories of accidents which should be significantly affected by the specific design features considered in this paper. These are:

1. Strandings
2. Collisions (ship to ship casualties)
3. Rammings (ship to object casualties)

While accidents such as structural failures or explosions may contribute to the total amount of accidental discharges, their occurrence should not be significantly affected by the changes considered here. Minor accidental sources such as leaking valves, overflows, etc. are likewise not considered here.

Although shell plating thickness which is the primary structural barrier to ramming varies little with ship size the contribution of rammings to accidental discharge is considered to be at least an order of magnitude less than that from strandings or collisions. This is particularly true of the large tankers considered by this paper for two principal reasons:

1. These ships do little maneuvering in the vicinity of bridge abutments and similar objects which are the source of most ramming incidents for smaller ships.

2. As the ships have grown in size it has become more important to control very precisely the speed at which they dock. This should reduce the incidence of pier rammings. Equally significant is the fact that in those cases when such a ramming does occur with a large tanker it is the pier rather than the ship which is most likely to be damaged. However, rammings have been included since the double side ships (250-C, 250-D) should be particularly effective in such an accident.

2. <u>Information Sources</u>

The analysis of effectiveness for accidental discharges is made difficult by the lack of applicable data. The amount of data available is small and it applies to ships older and smaller than the large tankers under consideration in this paper. The data that are available fall into several separate categories:

- Numbers of accidents, broken down into types (i.e., groundings, collisions, etc.) While data of this nature are quite plentiful, they are rarely related to an amount of oil spilled. For example, see references 1-5.

- Gross estimates of total amounts of oil spilled per year. These gross estimates are rarely broken down into amounts by accident type. Reference 2 contains data of this nature.

- Information on the effectiveness of double bottoms, double sides, etc. References 1 and 4 contain data of this nature. However, it is difficult to relate these data to a particular damage severity and oil outflow. Theoretical work being done in this area has not proven of use thus far. Correlation between these different types of data is poor. For example, if data on numbers of accidents are multiplied by outflow per accident as given by the IMCO Hypothetical outflow formula, the product is far in excess of the gross estimates given for accidental discharge.

While it might appear that the IMCO damage assumptions and hypothetical outflow calculations would be a satisfactory means of analysis, there are several additional factors which should be considered:

- The calculation of IMCO hypothetical outflow from stranding, O_s, was developed for freeboard draft ships. In a stranding, an excess freeboard ship of the type considered in this paper will have significantly higher outflow from a tank of the same volume as one in a freeboard draft ship. To take this effect into account, it is necessary to calculate outflow on the basis that, to achieve static equilibrium, the oil will flow out of the damaged tank until its head equals that of the sea. Excess freeboard will not affect the calculation of collision outflow since the entire tank volume is presumed to be lost.

- The calculation of the IMCO Hypothetical outflow (both O_c and O_s) assumes that the damage will occur at the "worst" location, that is, a bulkhead intersection where several tanks will be breached. While this type of severe assumption may be appropriate in the sense used by IMCO, there appears to be a high probability that damage will not occur in the most severe location.

- It is necessary to consider the consequences of those accidents where the penetration exceeds the IMCO damage assumption, particularly for the case of vertical penetration in double bottom ships.

3. Method of Analysis

The analysis of this section will be done on an individual ship basis. Subsection C will present a possible method for performing a similar analysis on the basis of the total number of ships in the fleet. For the reasons discussed in the previous sections, the analysis in this section will be carried beyond the IMCO Hypothetical Outflow calculations to include the other factors which need to be considered. Each of the three accidents under consideration - strandings, collisions and rammings - will be considered separately since available data does not permit an evaluation of the relative importance of collisions versus strandings.

4. Collision Damage

Table 10 presents the IMCO Hypothetical Outflow calculation (O_c) for each of the 250,000 DWT ships. The ships with double sides (250-C and 250-D) receive a credit in this calculation even though the double skin width is less than the IMCO damage criteria of B/5 or 11.5 m. Line 3 of Table 10 presents the outflow that would occur in those cases where the inner skin is ruptured. In this instance, the outflow from the double side ships is considerably

higher than for the single skin ships because of the large "inside" cargo tanks which can be designed into these ship types (line 2).

As discussed above the IMCO Hypothetical Outflow calculation considers a damage at the most severe location giving the maximum outflow for the extent of damage under consideration. This method can disguise real differences that may exist between different designs in the amount of outflow that would occur with an average or more likely damage location. To determine the relative effectiveness of the designs involved an investigation was made to find average outflow for all possible damage locations in the cargo tank length of each ship. By using a range of damage lengths from 1 meter to 35 meters, it was found that the <u>relative</u> amounts of outflow from each of the eight 250,000 DWT ships are nearly independent of damage length. The results of these calculations are presented in line 1 of Table 11 for a damage length of 14.5 meters. It is necessary to credit the double side cases for that percentage of incidents where the inner skin is not ruptured. The effectiveness of double sides was evaluated. However, since the available data is for tankers considerably smaller than the large tankers under consideration here, they were examined both in terms of absolute penetration depth in meters, and in terms of penetration depth related to the breadth of the struck ship. Recognizing that the average ship generally has been increasing in size, it is felt that the magnitude of penetrations will lie somewhere between values independent of ship size and values which are proportional to ship's

TABLE 10 Collision Damage - IMCO Hypothetical Outflow

	SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1)	Cargo Tanks Damaged (Most Severe Location) Note A	4BP,5P	4P,5P	5P,6P	5P,6P	2P,3P	2P,3P	4P, Sludge T	5P, Sludge T
2)	Volume of Tanks Damaged (m^3)	28,700	44,800	29,900	28,500	35,000	40,200	26,100	28,800
3)	Outflow if Tanks Are Damaged-Note B	28,700	44,800	29,900	28,500	35,000	40,200	26,100	28,800
4)	IMCO Hypothetical Outflow,Oc(m^3)-Note B	28,700	44,800	29,900	28,500	23,100	14,800	26,100	28,800

NOTES:

A. For double skin cases (250-C, 250-D) damage is assumed beyond inner skin since skin tank width is less than B/5 or 11.5 m.

B. IMCO hypothetical outflow calculation reduces O_c for double skin ships (250-C, 250-D) However, possibility of damage beyond the inner skin must be recognized. In those cases outflow will be as shown in line 3.

TABLE 11 Collision Damage - Outflow From "Average" Collision

SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1) Average Outflow if 1 or more tanks are breached in a collision(m^3) - Note A	17,400	21,900	18,300	17,600	17,300	21,500	13,700	11,400
2) Likelihood of breaching tank(s) (%) Note B	100	100	100	100	70	45	100	100
3) Statistical Outflow (m^3)	17,400	21,900	18,300	17,600	12,100	9,700	13,700	11,400
4) Relative Statistical Outflow (250IMCO=100)	100	126	105	101	70	56	79	66

NOTES:

A. Assumed damage length of 14.5 m, considering all possible damage locations in cargo tank length. Also assumes that entire contents of damaged tanks are lost.

B. Credits double side cases (250C, 250D) as described in the text. Single skin case likelihood equals 100% where the outer skin will not be penetrated and no pollution will occur.

breadth. Using the mean of the values from these two estimates, the following values of effectiveness have been assumed:

TABLE 12 Double Side Effectiveness

Ship	Double Side Width	Effectiveness in Collision
250-C	3.5 m	30%
250-D	6.55 m	55%

This information is given in line 2 of Table 11 where the likelihood of breaching tanks = 1 - effectiveness in collision. It must be noted that although the likelihood value for single skin ships is defined as 100% in the context of this table, there will still be many collisions in which there are no tanks ruptured, and there is no pollution. For example, reference 2 indicates that of 338 tanker collisions that occurred in 1969-1970, 76% did <u>not</u> result in pollution.

Line 4 of Table 11 presents the relative outflow that will occur in an "average" collision, giving credit for double sides. The following points appear significant:

- In comparison to the base ship, double sides may reduce collision outflow significantly.
- Collision outflows for the double bottom only ships (250-B1, and 250-B2) may be essentially the same as for the base ship.

- Existence of staggered ballast wing tank (250-E1 and 250-E2) may provide a significant reduction in collision outflow which is of similar magnitude to that provided by the double sides of 250-C and 250-D. It should be noted that use of the IMCO Hypothetical Outflow Calculation (as shown in line 4 of Table 10) does not reflect the effectiveness of the staggered ballast wing tanks.

5. Stranding Damage

As discussed above, the calculation of the IMCO Hypothetical Outflow in stranding, O_S, may be misleading if applied literally to the ships considered in this study. Table 13 presents the IMCO Hypothetical Outflow and also contains a recalculation which considers the following factors:

- To account for the excess freeboard which exists in all but the base case, a static equilibrium calculation has been performed. This assumes that oil will flow out of damaged tanks until the static head of the oil remaining in the tank equals that of the sea outside. To include such factors as tide, current, and ship rise, the draft of the ship is considered to be reduced by 2 meters. Figure 5 demonstrates this calculation.

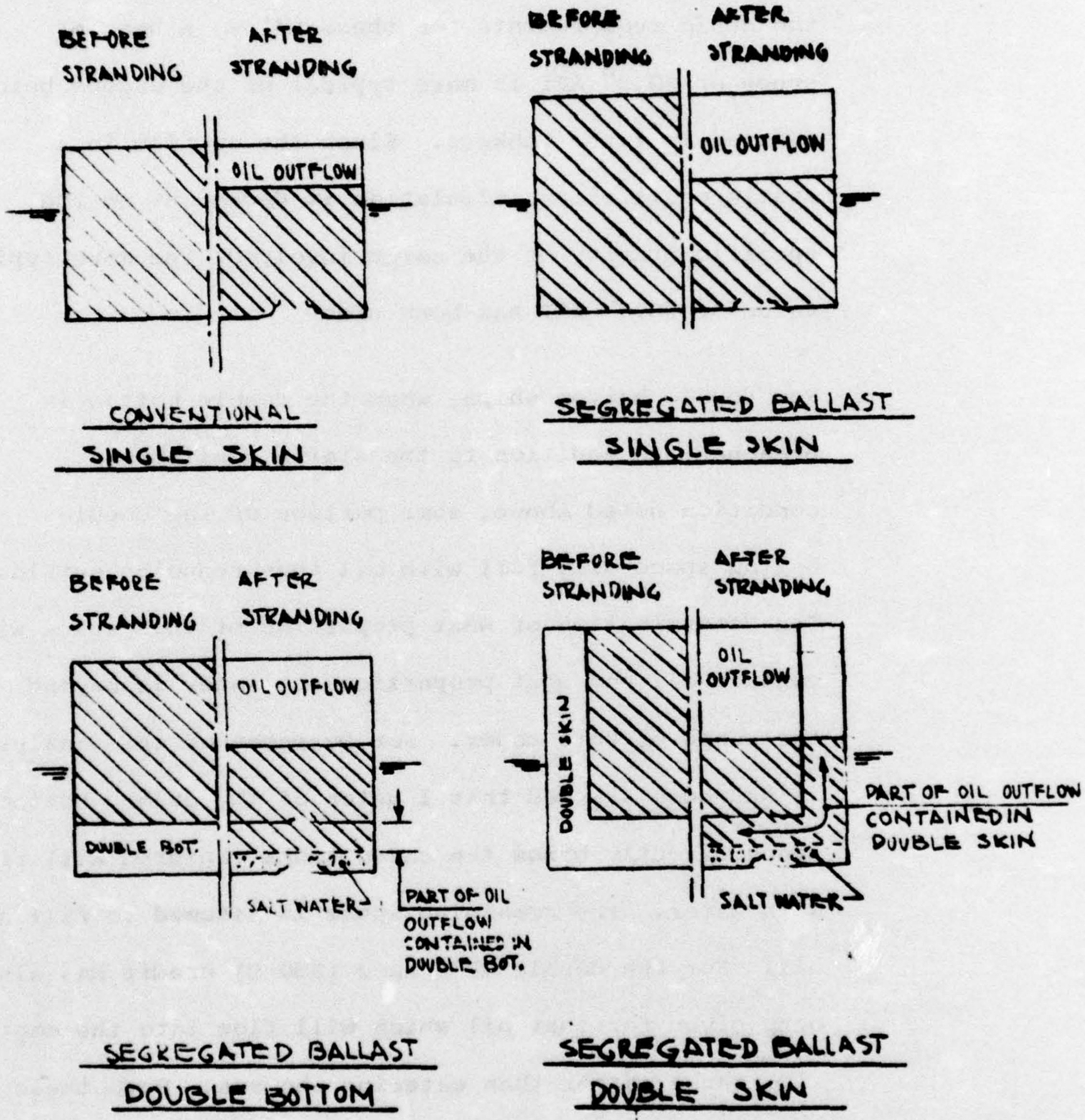


FIGURE 5

OIL OUTFLOW FROM STRANDING

- Although a crude oil of 38° API was used to determine the cubic requirements for these ships, a heavier crude of 30.3° API is more typical of the crudes being carried in large tankers. Since the outflow in a static equilibrium calculation is dependent on the specific gravity of the cargo involved, the more typical value of 30.3° API has been used.

- For double bottom ships, when the double bottom is breached, in addition to the static equilibrium condition noted above, some portion of the double bottom space will fill with oil thus reducing outflow. The determination of what proportion of this space will contain oil and what proportion sea water is beyond the scope of this paper. For purposes of this analysis, it has been assumed that 1 meter of the double bottom space directly below the cargo tanks ruptured will fill with water. The remaining space is assumed to fill with oil. For the double skin case (250-C) credit has also been given for that oil which will flow into the empty side tanks rather than entering the sea. Both these factors are demonstrated in Figure 5.

When these physical considerations are applied to the Hypothetical Outflow calculation, the Expected Outflow for damage in the most severe location is found (line 4, Table 13).

TABLE 13 Stranding Damage - IMCO Hypothetical Outflow And Expected Outflow For Most Severe Damage Location

SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1) Cargo Tanks Damaged - Most Severe Location - Note A	4℄,5℄ 4BP,5P	4℄,5℄ 4P,5P	1℄,3℄ 1P	1℄,3℄ 1P	4℄,5℄ 4P,5P	1℄,2℄ 1P,2P	4℄,5℄ 4P	4℄,5℄ 5P
2) Volume of Tanks Damaged (m^3)-Note A	84150	112650	91350	94100	122300	120250	88550	85350
3) IMCO Hypothetical Outflow (m^3)	28050	37550	0	0	0	30000	29500	28500
4) Expected Outflow for Most Severe Location (m^3) - Note B	15000	20600	20900	19700	34600	40800	25000	28500

NOTES:

A. For double bottom ships (250-B1, B2, and C) damage beyond double bottom is assumed for calculation of line 4. For IMCO hypothetical outflow, no cargo tanks will be damaged on the double bottom ships.

B. For 30.3° API, assuming equal static head of oil remaining in tank and sea. Draft decreased by 2m to account for ship rise, tide, current. For double bottom ships, calculation gives credit for oil remaining in double bottom and for case 250 C for oil entering skin tanks.

In considering Table 13, several points should be noted:

- While the IMCO Hypothetical Outflow calculation considers the outflow from the three double bottom cases (250-B1, 250-B2, and 250-C) to be zero there will certainly be instances when the double bottom will be breached.

- The expected outflow using the static equilibrium calculation is considerably less than the equivalent IMCO Hypothetical Outflow for the freeboard draft ships. As the amount of excess freeboard increases, the expected outflow increases significantly. For the deepest ships (250-C, 250-D, and 250-E2) the 1/3 factor in the IMCO Hypothetical Outflow calculation is reached.

Even with the modifications to the IMCO Hypothetical Outflow calculation that were incorporated in the calculation of line 4 of Table 13, it must be remembered that line 4 still represents an accident occurring at the most severe location. As in the case of collisions, consideration of only this one damage location may not reveal real differences that exist between the various designs. For this reason, a calculation of the outflow from an "average" stranding incident has been made and is presented in Table 14.

TABLE 14 Stranding Damage - Outflow From "Average" Stranding

SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1) Expected Outflow for most severe location (m^3) (Table III, Line 4)	15,000	20,600	20,900	19,700	34,600	40,800	25,000	28,500
2) Estimated Ratio of Average Stranding Outflow to Outflow for most severe location - Note A	.33	.31	.33	.32	.31	.30	.29	.28
3) Likelihood tanks will be breached (%) (Note B)	100%	100%	39%	36%	39%	100%	100%	100%
4) Statistical Outflow (m^3)	4,950	6,400	2,700	2,300	4,200	12,200	7,250	8,000
5) Relative Statistical Outflow (250 IMCO = 100)	100	129	54	46	85	247	146	161

NOTES:

A. Converts most severe stranding involving 3 or 4 cargo tanks to "average" stranding where less tanks will be involved in most cases.

B. Credits double bottom cases (250-B1, B2, C) as described in the text.

Line 1 of Table 14 is taken directly from line 4 of Table 13 and represents a realistic estimate of outflow from damage occurring at the worst location. As can be seen in Table 13, this worst location involves either 3 or 4 cargo tanks. A calculation was performed to estimate in what percentage of strandings less tanks would be damaged. It was found that outflow in an "average" stranding would vary from .28 to .33 of the outflow for the most severe location. These ratios are presented in line 2 of Table 14. It was then necessary to estimate as well the effectiveness of a double bottom. Reference 1 and 4 contain data relevant to this analysis. Based on the following analysis, the effectiveness of the three double bottoms is shown in Table 15. Reference 1 shows that on the average inner bottoms are likely to remain intact in 43% of stranding accidents. By plotting all 75 stranding accidents in Reference 4 where bottom penetrations are known the following can be derived:

- In 79% of cases, penetrations did not exceed 6.7% of ship breadth
- In 85.5% of cases, penetrations did not exceed 8.5% of ship breadth

The data also show that while inner bottoms are more likely to be breached when penetrations are deep, in several instances they were breached where penetrations did not reach double bottom height. Accordingly, in order to assign partial credit to deeper double bottoms an average value was used as follows:

For designs 250-B1 and 250-C (double bottom equal to 6.7% breadth)

From Average double bottom height analysis	43% effective
From Penetration analysis	79% effective
Average Value of effectiveness	61%

For design 250-B2 (double bottom equal to 8.5% breadth)

From Average double bottom height analysis	43%
From Penetration analysis	85.5%
Average Value of Effectiveness	64%

TABLE 15 Double Bottom Effectiveness

Ship	Double Bottom Height	Effectiveness
250-B1	3.45 m	61%
250-B2	4.42 m	64%
250-C	3.50 m	61%

These data are presented in line 3 of Table 14 where likelihood that tank(s) will be breached = 1 - Effectiveness. By applying the factors of lines 2 and 3 to line 1 a so-called "statistical" outflow is reached which is then converted to a relative outflow in line 5 with 250-A IMCO as the base case.

The following points appear significant:

- A double bottom can provide a significant reduction in outflow from stranding. For cases 250-B1 and 250-B2,

there is a reduction of about half when compared to base. If considered on comparable bases as to segregated ballast amount and freeboard (250-B2 vs. 250-E1) the effect of the double bottom is seen to be more nearly a 3 to 1 reduction in stranding outflow. Little improvement is realized in 250-C because of larger "inside" tanks and because of increased freeboard beyond that for 250-B1 and 250-B2.

- Increased freeboard significantly increases outflow from stranding. Ships 250-D, 250-E1, and 250-E2 which have no double bottom to offset their increased freeboard have outflow increases of from 46% to 147% of the base ship.

- In determining the effectiveness of the double bottom ships it has not been possible to include the following factors:

  1. The extent of damage to the inner bottom is likely to be less than that to the outer skin. This would mean that in some cases where more than 1 tank is ruptured in a single bottom ship, fewer tanks may be ruptured in the double bottom ship.
  2. Also, the smaller area of damage should serve to decrease the rate at which the cargo flows out, permitting more time to transfer cargo out of the damaged tank(s).

Both of these factors tend to further increase the effectiveness of the double bottom ships.

6. Rammings

Rammings will not be analyzed in detail in this section. However, they will be considered in Subsection C. For that analysis, it will be assumed that the double sides in 250-C and 250-D will be 100% effective in eliminating pollution from this source.

7. General Discussion

In the beginning of this discussion of accidental pollution it was noted that there was not sufficient data available to permit evaluation of the relative magnitude of the outflow from strandings versus collisions. It might appear that such a relationship could be defined by comparing line 3 of Table 11 with line 4 of Table 14 since both present outflow from a statistical or average outflow. However, such a comparison does not appear valid and hence was not made.

The difficulty in using these numbers to determine the relative importance of collisions versus strandings can be seen in the following:

- Comparing the statistical outflows for ship 250-A which is typical of many in service today indicates that an average collision results in $3\frac{1}{2}$ times as much overflow as an average stranding.

- Data from reference 2 indicates that the frequency of accidents and pollution incidents involving strandings and collisions is approximately the same.
- If the information from these two items is combined, it would appear that collisions would account for at least $3\frac{1}{2}$ times as much outflow as strandings. However, the small amount of data available on this subject (reference 3) does not support such a conclusion. Instead, the data of reference 3 indicate that strandings are a more significant source of accidental pollution than collision.

In spite of this difficulty, it is believed that the relative statistical outflow data given in Tables 11 and 14 give a valid comparison of effectiveness between different designs. It is possible to compare the last lines of these two tables and make general observations on the overall effectiveness of the various designs under consideration. However, it must be remembered that these tables cannot be used to determine the relative magnitude of outflow from collisions and strandings. If one of these is far more significant than the other, the relative effectiveness for the more significant source obviously predominates.

- The only ship which reduces both stranding and collision outflow is the double skin ship 250-C. However, the effectiveness of the double bottom is to a large extent negated by the increased freeboard.

- The double bottom ships (250-B1 and 250-B2) reduce stranding outflow by half, but have no effect on collision outflow.

- The staggered ballast tank ships (250-E1 and 250-E2) and the double side only ship (250-D) provide some reduction in collision outflow but have significantly greater stranding outflow because of their increased freeboard.

C. <u>Pollution Effectiveness From Operation and Accidental Discharges On A Fleetwide Basis</u>

It was mentioned earlier in Subsection B that if data on number of accidents are multiplied by the IMCO hypothetical outflows the product far exceeds gross estimates of accidental discharges on a total tanker fleet basis. Similarly if numbers of accidents are multiplied by the statistical outflows presented in Tables 11 and 14 the product again exceeds gross estimates of total outflow. This is not surprising in that significant numbers of accidents are known to have occurred in which the outflow was considerably less than would be predicted by either of the rather severe sets of assumptions discussed in Subsection B. It is for this reason that an effort was made, in this section, to look at the total accidental outflow and apportion it on a per ship basis, to strandings, collisions and rammings. In an approximate manner, those values then could be further compared with operational

discharges. A further relation to incremental costs of segregated ballast designs can be found resulting in some measure of cost effectiveness.

It should be clearly understood, however, that these estimates of overall effectiveness are based on a series of approximations including:

- Historical estimates of outflows from all accidents
- New ship projections of outflows from all accidents
- Apportionment of outflows by type of accidents
  - historical
  - projected to cover new ships

These estimates further highlight the critical need for historical data on accidents showing quantities of oil outflow. Study VI should provide further input.

Outflow Due to Collisions, Strandings and Rammings

Recent estimates of tanker oil outflows from all casualties are in the range of 100-250,000 tons per year or an average of 175,000 tons corresponding to 200,000 m^3 (@ 30^{o}API). That due to collisions, strandings, and rammings is assumed to be 100,000 m^3.

- 1969-1970 data (reference 2) show that the number of collision accidents resulting in pollution approximately equals stranding accidents.

- 1969-1970 ICS data (reference 3) on major accidents show outflow resulting from stranding accidents has been roughly 10 times as much as outflow from collisions.

- Regarding rammings it is felt that they might represent a significant number of occurrences for small ships, but for large tankers they would be very small in terms of quantities of oil outflow, probably less than 1%.

By assuming partial credence to the 10 to 1 strandings to collisions ratio of reference 3 and considering that IMCO regulations might tend to equalize outflows from collisions and strandings, the following relative outflows were assumed:

Strandings	66%
Collisions	33%
Rammings	1%

Theoretically a projection of accidental oil outflow from future ships should consider all of the following:

- Total deadweight of all tankers
- Size, average deadweight of each tanker
- Number of tankers
- Areas to which tankers of various sizes can trade
- Accident prevention programs such as

- Personnel training

- Traffic control

- Improved Navigation and Collision Avoidance aids

Being unable to presently weigh the importance of each of the above, an extrapolation covering simply the increase in total deadweight was developed as follows:

	1970	1980
Tanker Requirements T-2 equivalents	10,500	22,000

	1970 Fleet After Obsolescence	Under Contract or Constr. now	New Contracts for 1980 or Earlier Del'y
Make up of 1980 requirements in T2 equivalents	7000	6000	9000
Assume requirements for persistent oil 90% of above	6300	5400	8100

The above indicates there are requirements for 8100 T2 equivalents to be contracted for and delivered between now and 1980. From the other assumptions above annual oil outflow due to strandings, collisions and rammings, from these 8100 T2 equivalents, would be:

$$100{,}000 \text{ m}^3 \text{ (1970 outflow)} \times \frac{\text{8100(new T2 equiv.)}}{\text{10500(1970 T2 equiv.)}} = 77000 \text{ m}^3$$

8100 T2 equivalents correspond to approximately

$$\frac{\text{8100 (T2)} \times \text{16600 (T2 DWT)} \times \text{14.6 Kts (T2)}}{\text{250,000 (DWT)} \times \text{16.0 Kts (250MDWT)}} = \underline{490} \text{ equiv. 250MDWT}$$

$$\text{Oil outflow/250-A/year} = \frac{77000}{490} = \underline{\text{157 cu. m.}}$$

Apportioning these 157 cubic meters in accordance with the 66%, 33%, 1% earlier assumption, the outflow for a 250-A type ship would be:

			Annual Outflow Typical 250-A
Strandings	$0.66 \times 157\ m^3$		$103\ m^3$
Collisions	$0.33 \times 157\ m^3$		52
Rammings	$0.01 \times 157\ m^3$		2
		TOTAL	$157\ m^3$

Using the relative statistical outflows for each accident, shown in line 4 of Tables 11 and line 5 of 14 presented earlier, and the volumes of outflows for a 250-A shown above, the first 3 lines of Table 16 were developed showing possible outflows apportioned on a per ship basis. As an example the 43 cubic meters value shown in line 1 for 250-B1 was derived by multiplying:

$$(103\ m^3 \text{ above}) \times \underset{(\text{Table 14})}{(54\% \text{ for 250-B1})} / \underset{(\text{Table 14})}{(129\% \text{ for 250-A})} = 43\ m^3$$

Line 4 shows total outflow due to accidents on a per ship per year basis. By subtracting total outflow of each design from the base case 250 IMCO, the effectiveness of each design is derived in terms of preventing oil outflow compared to the base case, as shown in line 5. From Table 5 in Section IV, differences of total annual costs over base case have been calculated and are shown in line 6. Line 7 (line 6 divided by line 5) presents a measure of cost effectiveness for the various designs in reducing oil outflow from

TABLE 16 Fleetwide Oil Outflow Estimates From Accidents
Apportioned On A Per 250 MDWT, Per Year Basis

	SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1)	Stranding Outflow, m^3	80	103	43	37	68	197	117	129
2)	Collision Outflow, m^3	41	52	43	41	29	23	33	27
3)	Ramming Outflow, m^3	2	2	2	2	0	0	2	2
4)	Total Accidental Outflow, m^3	123	157	88	80	97	220	152	158
5)	Oil Outflow prevented (exceeded) compared to base case, m^3	Base Case	(34)	35	43	26	(97)	(29)	(35)
6)	Amount total annual costs exceed base case 250 IMCO, \$M	Base case	-39	282	418	822	527	227	489
7)	Cost of preventing oil outflow from accidents, \$/yr./m^3	Base case	-1,150*	8,050	9,700	31,600	← Oil outflow increases and cost increases		

*The pre-IMCO 250 A design shows an <u>increase</u> in oil outflow at a cost <u>saving</u> of \$1,150/m^3.

accidents. It is expressed in $ per year of preventing the discharge of an additional cubic meters of oil in accidents. It should be considered of course in conjunction with the total quantity of outflow prevented (line 5).

The following become apparent from Table 16:

- A 25-35% reduction in accidental outflow is shown by double bottom designs 250-B1 and 250-B2 and double skin design 250-C; the maximum reduction is shown by double bottom design 250-B2.

- On the basis of equal segregated ballast capability (45% of full load displacement) Table 16 shows a 50% reduction in outflow is achieved by the double bottom designs as contrasted to the single skins (comparison of designs 250-B2 with 250-E1).

- The double side and both single skin designs 250-D, 250-E1 and 250-E2 shows significant increases in accidental outflows over the base case 250 IMCO design. Since all three designs are also more costly to build, these are not cost effective for the accidents considered.

- Design 250-B1 shows the least incremental cost to reduce accidental discharges, while design 250-B2

shows a 20% higher cost per ton with a likely capability to reduce oil outflow by an additional 20-25% over the 250-B1 design.

- Although double skin design 250-C can also reduce oil outflow (about 25% less than 250-B1), it costs about 3-4 times as much to save a cubic meter of outflow, as does the 250-B1 and 250-B2 designs.

Oil Outflow from Operational Discharges

Oil outflows from operational discharges on a per ship, per voyage basis, were discussed and presented earlier in Table 9. By assuming 7 voyages per year as a typical 250MDWT voyage (a mixture of mostly long voyages with some short ones) operational discharges were converted on a per ship per year basis and are also shown in Tables 17 and 18.

Overall Assessment of Outflow from Accidents and Operations

Having converted the discharges from normal operations on a per ship per year basis as described above, Tables 17 and 18 combine outflows from accidents and normal operations for 45% and 60% ballast operations respectively. These tables, similar in format to previous Table 16, show in line 4 the decrease in outflow over base case 250-A IMCO design due to normal operations and accidents. Line 6 shows the cost/per year of preventing an additional discharge of 1 cubic meter of oil.

TABLE 17

Fleetwide Oil Outflow Estimates From Operational And Accidental Discharges Apportioned on a Per 250 MDWT, Per Year Basis

	SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1)	**Total Accidental Outflow, m^3**	123	157	88	80	97	220	152	158
2)	**Total Operational Outflow*** **- Case 1, 45% Displ., m^3**	129	125	36	6	6	41	41	41
3)	Total Outflow **- 45% Displ., m^3**	252	282	124	86	103	261	193	199
4)	**Oil Outflow prevented compared to base case, 250 IMCO, m^3**	Base Case	(30)	128	166	149	(9)	59	53
5)	**Amount of Total annual costs** exceed base case 250 IMCO, $M	Base Case	-39	282	418	822	527	227	489
6)	**Cost of preventing oil outflow from operations only operating @ 45% ball. displ., $/yr/$m^3$**	Base Case	-	**3,030**	3,400	6,680	5,980	**2,580**	5,550
7)	Cost of preventing oil outflow from accidents and operations operating @45% ball. displ., $/yr/$m^3$	Base Case	-	2,200	2,500	5,550	Outflow increases & Cost increases	3,900	9,200

* Assumes present practice LOT, cycle 1 in Table 9

TABLE 18 Fleetwide Oil Outflow Estimates From Operational and Accidental Discharges Apportioned On A Per 250 MDWT, Per Year Basis

SHIP	250-A IMCO	250-A	250-B1	250-B2	250-C	250-D	250-E1	250-E2
1) Total Accidental Outflow, m^3	123	157	88	80	97	220	152	158
2) Total Operational Outflow* -Case 1, 60% Displ., m^3	171	157	64	58	6	41	88	41
3) Total Outflow - 60% Displ., m^3	294	314	152	138	103	261	240	199
4) Oil Outflow prevented compared to base case, 250 IMCO, m^3	Base Case	(20)	142	156	191	33	54	95
5) Amount of Total annual costs exceed base case 250 IMCO, $M	Base Case	-39	282	418	822	527	227	489
6) Cost of preventing oil outflow from operations only operating @60% ball. displ., $/yr/$m^3$	Base Case	-	2,600	3,700	5,000	4,050	2,740	3,750
7) Cost of preventing oil outflow from accidents and operations operating @60% ball. displ., $/yr/$m^3$	Base Case	-	1,986	2,679	4,304	15,970	4,204	5,147

* Assumes present practice LOT, cycle 1 in Table 9

The following can be observed from Tables 17 and 18:

- A 2-3 fold reduction in oil outflow from accidents and operations is shown as possible by double bottom designs 250-B1, 250-B2 and double skin design 250-C, line 3 of both tables.

- On the basis of equal segregated ballast capability a better than 40% reduction in outflow is likely to occur with double bottom designs as contrasted to single skin designs (comparison of 250-B2 with 250-E1).

- Examination of line shows the lowest cost of saving 1 cubic meter of oil outflow is likely to be achieved by the double bottom designs.

- Double skin design 250-C appears capable of saving about the same oil outflow as the double bottom designs but at twice the cost.

- Single skin designs show smaller likely reductions in oil outflow, but at costs per ton that are about twice those for the double bottom designs.

- The double side design (250-D), at the 45% ballast displacement, actually shows an <u>increase</u> in outflow with increasing cost (it shows somewhat better performance at a 60% ballast displacement).

In looking at these numbers the following must especially be born in mind:

- The cost effectiveness of accidental outflows shown above are the result of one set of assumptions in regard to extrapolation to future accidental outflows. For this reason a sensitivity study was conducted as described below.

Sensitivity to Outflow Assumption

The total annual outflows estimated in the preceding section were the result of many assumptions already discussed. One of the more critical assumptions affecting the relative performance of each design in abating pollution were the relative outflows assumed for strandings, collisions and rammings. These were 66%, 33% and 1% respectively. To provide a broader base for evaluating the impact of this assumption similar outflow, calculations were performed for both ballast modes and extreme relationships among strandings, collisions and rammings. The sensitivity study assumed ratios of 90% strandings, 9% collisions and 1% ramming as one extreme and 22% strandings, 77% collisions and 1% rammings as another. These extremes were arrived at by assuming the admittedly sparse sample of data in reference 3 showing the 10 to 1 ratio between stranding and collision outflows was correct; and alternatively the $3\frac{1}{2}$ to 1 ratio between collision and stranding outflows indicated by Tables 11 and 14 was valid. Again it should be stressed

that neither of these extremes are considered correct and the very divergence points up to the pressing need for a wider and more reliable statistical data base.

On the basis of these assumptions fleetwide oil outflow estimates from operational and accidental discharges were made similar to those of Tables 17 and 18. Figure 6 shows the average annual outflow for each design on the 250 series for the 60% ballasted displacement operating mode. From this figure the following trends can be observed:

- The double skin design (250-C) has the lowest average annual outflow over the entire range of stranding/ collision ratios.
- Double bottom designs exhibit a trend toward decreasing outflow as strandings become dominant. Even when collisions predominate ($3\frac{1}{2}$ to 1) the poorest double bottom design (250-B1) has only 23% more outflow than the best non-double bottom alternative. At a $3\frac{1}{2}$ to 1 outflow ratio with strandings predominating the double bottom design has over 45% less outflow than the best single bottom version. The break even point lies between 33% and 40% of the total accidental outflow due to stranding.
- The double side design (250-D) has a very high slope which indicates it has greater outflow than the base

FIG. 6-SENSITIVITY OF AVERAGE ANNUAL OIL OUTFLOW TO RELATIVE OUTFLOWS - STRANDING vs. COLLISIONS
(60% BALLAST DISPLACEMENT)

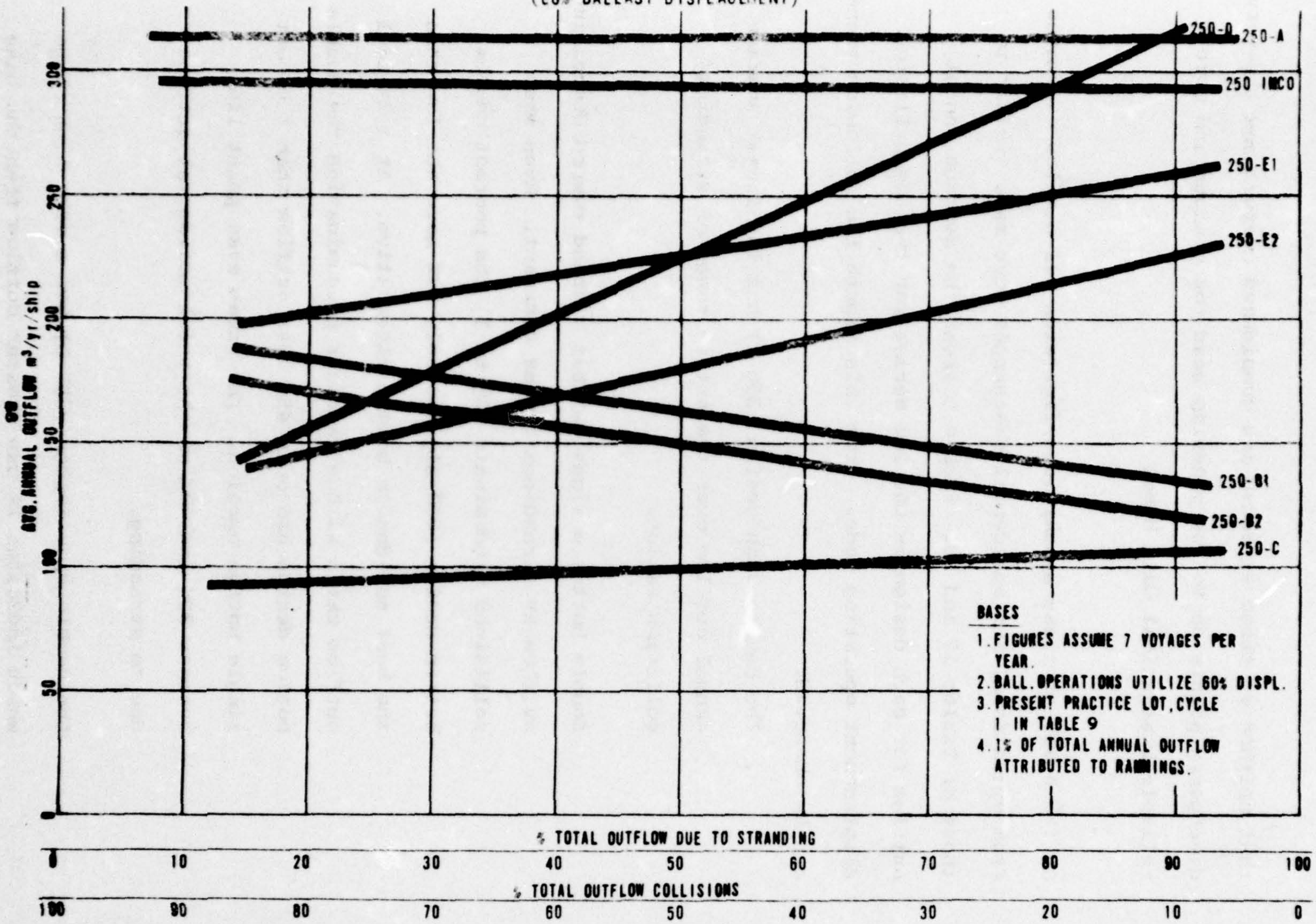
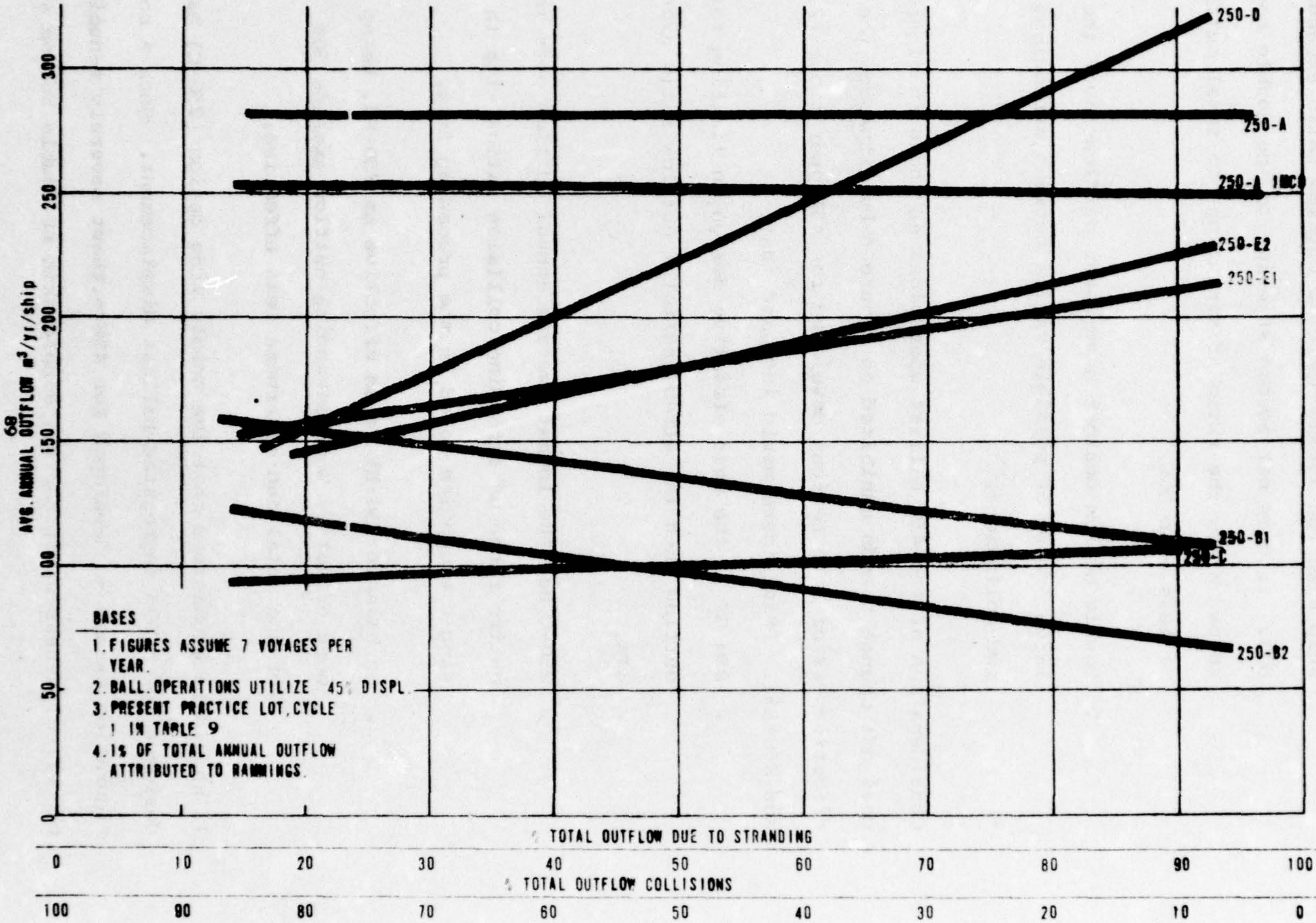


FIG.7-SENSITIVITY OF AVERAGE ANNUAL OIL OUTFLOW TO RELATIVE OUTFLOWS - STRANDING vs. COLLISIONS
(45% BALLAST DISPLACEMENT)



ship when the stranding/total outflow ratio exceeds 80%. It does not become superior to the double bottom ships unless the ratio of strandings to total outflow is less than 30%.

- Double bottom designs have lower outflows over the larger range of possible ratios between strandings and collisions.

Consideration of the 45% ballast operations as shown in figure 7 does not change trends exhibited on figure 6 but improves the effectiveness of both designs developed for 45% operations (250-B2 and 250-E1). This figure would indicate that:

- 250-B2 is the most effective design in limiting total outflow when the stranding/total outflow ratio exceeds 47%.

- 250-C has the lowest average annual outflow over the entire range of stranding/collision ratios with the single exception noted in the preceding item.

- On balance 250-E1 is an effective as 250-E2, being more effective when stranding outflow exceeds 50% of the total and otherwise less effective.

It should be emphasized that the double side design (250-C) has been designed for a 60% segregated ballast displacement. Such a configuration cannot be developed for 45% without severely reducing the effectiveness of either the double skin or double bottom since

FIG.8 - SENSITIVITY OF COST EFFECTIVENESS TO RELATIVE OUTFLOWS OF STRANDING vs. COLLISIONS
(60% BALLAST DISPLACEMENT)

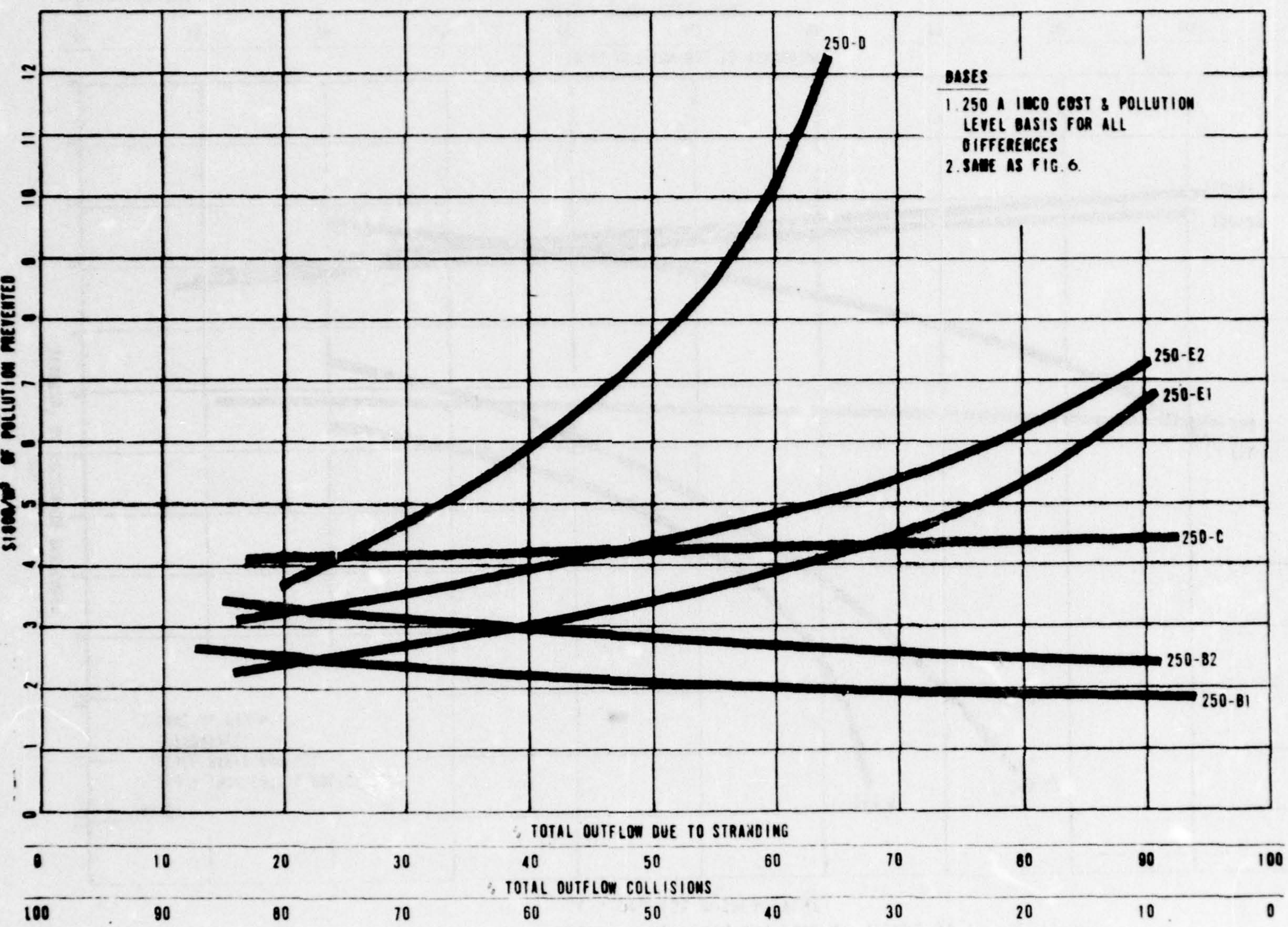
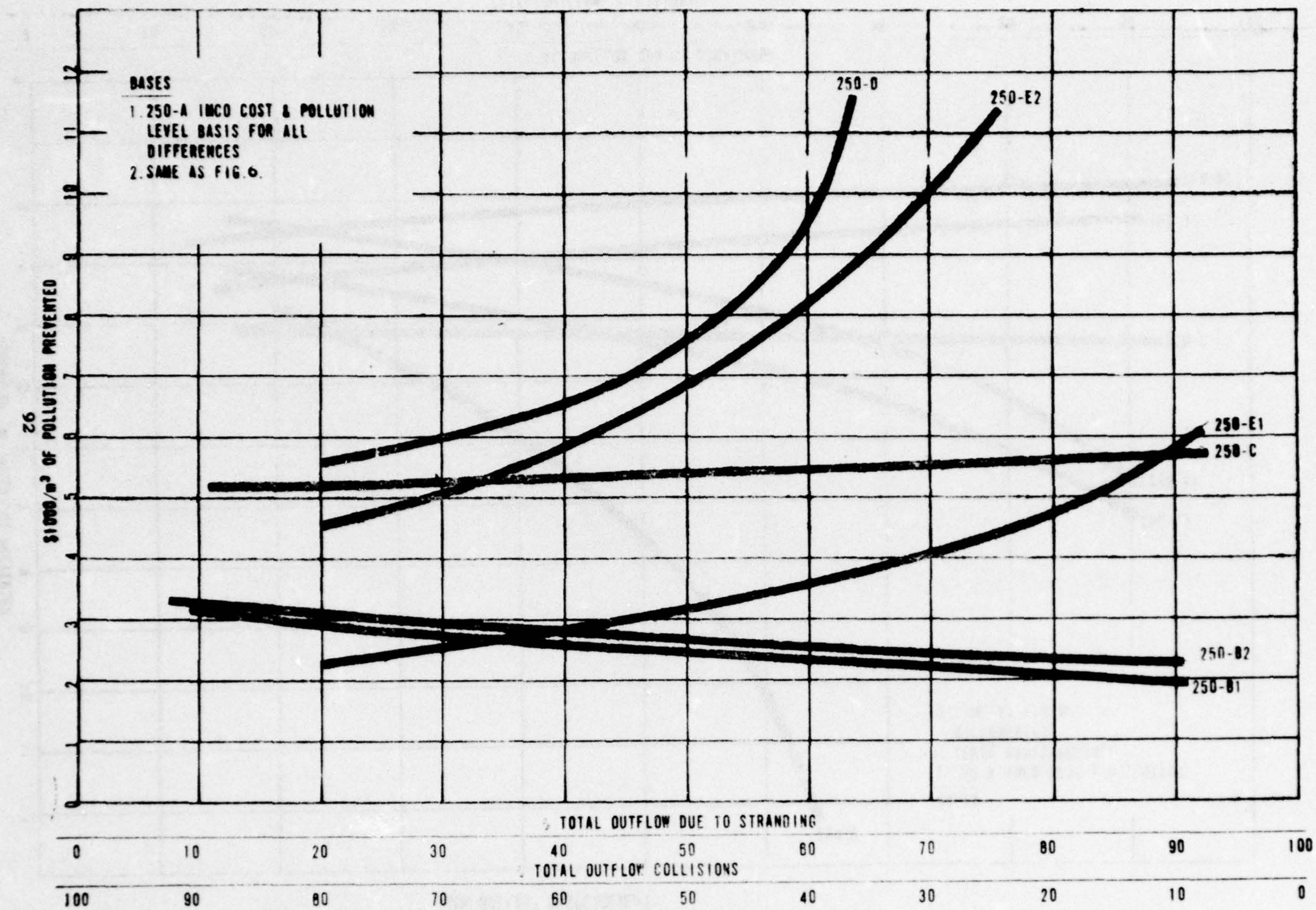


FIG. 9 SENSITIVITY OF COST EFFECTIVENESS TO RELATIVE OUTFLOWS OF STRANDING vs COLLISIONS
(45% BALLAST DISPLACEMENT)



the non-cargo carrying volumes must be kept similar to 250-C, as designed, for adequate protection. This protection inherently provides about 60% displacement.

Since absolute outflows can only be of interest if something is known relative to the acceptable limits of oil in the sea or if the financial resources to limit outflow are boundless, a similar set of curves for cost effectiveness (figures 8 and 9) were developed.

Figure 8 for the 60% ballast displacement cases lends itself to the following observations:

- The B/15 double bottom design (250-B1) is the most cost effective over the major portion of the range of stranding outflows (i.e., stranding outflows exceeding 22% of the total accidental outflow).
- All versions are relatively close to one another for a collision to stranding ratio of 3½ to 1.
- The sharp upward curvature exhibited by the single bottom ships (250-D, 250-E1 and 250-E2) causes them to diverge rapidly from comparability with double bottom ships as the percentage outflow due to stranding increases.

- The double skin ships (250-C) cost effectiveness is relatively insensitive to variations in stranding versus collision outflows.

A similar plot (figure 9) for the 45% ballast mode shows similar trends but with the performance of the 60% ballast displacement designs degraded (250-C, 250-D and 250-E2) and those designs for lower ballast amounts showing improvement. Specifically, the following trends are evident:

- 250-B2 is nearly as cost effective as 250-B1.
- The conventional 45% ballast configuration, 250-E1, is most cost effective when stranding outflows are less than 34% of the total.
- As in the 60% mode, single bottom ships diverge rapidly from double bottom designs as stranding outflow increases.

In conclusion a word of guidance concerning the application of the foregoing analysis is in order.

- The relative costs in saving oil outflow from operational pollution must still be compared on equal bases with alternative measures, notably those being studied by IMCO studies II, III, IV and V in frame of reference set by IMCO study VI.

- Due consideration should be given to alternate means of preventing accidents already mentioned, i.e., personnel training, traffic control, improved collision avoidance and navigation aids.

SECTION VI OTHER OPERATIONAL FACTORS

This section discusses other operational factors which should be considered in evaluating segregated ballast tankers, but which have not been examined in sufficient detail to reach precise conclusions.

A. Effect Of Increased Freeboard On Shore Facilities

As shown in Table 19, each of the segregated ballast designs has a significant increase in freeboard over the base case, ranging from 42 to 115 percent.

In ballast, the percent increase is less, but for any ballast displacement the absolute increase in freeboard is the same as in full load. Because of the lighter displacement and already large sail area (above water profile), the ballast condition may well be the critical case.

This increase in freeboard will affect shore facilities in several areas. The loading/discharge arms presently designed to accommodate ships of conventional freeboard may require modifications in order to be able to receive segregated ballast ships. The increased freeboard may also necessitate modifications to the mooring arrangements, both because of the changed lead angles involved and because of the increased windage that will result from the increased sail area.

TABLE 19 Increase in Freeboard - Full Load

Ship	Freeboard (m)	Increase Over Base Case m	Increase Over Base Case %
120-A	4.9	Base	Base
120-C	9.5	4.6	94%
250-A	5.8	Base	Base
250-B1	8.2	2.4	42%
250-B2	9.8	4.0	68%
250-C	12.5	6.7	116%
250-D	11.9	6.1	105%
250-E1	9.2	3.4	58%
250-E2	11.9	6.1	105%
500-A	7.2	Base	Base
500-E1	12.6	4.7	59%

It is expected that these modifications would increase the cost of the shore facilities somewhat. In order to quantify this amount it would be necessary to investigate the individual shore facilities involved since there can be significant differences among the facilities.

B. Effect Of Increased Freeboard On Ship Controllability

The increase in sail area that results from the increased freeboard can be expected to have a significant effect on ship controllability, particularly in wind at low ship speeds as occurs in harbor and docking situations. This could require the availability of increased control forces either in the form of ship mounted devices such as lateral thrusters or as additional tugs.

C. Other Factors

The use of double bottom tanks for segregated ballast may result in muck buildup in these tanks which would be difficult to clean.

REFERENCES

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2. J. D. Porricelli, V. F. Keith, and R. L. Storch, "Tankers and the Ecology," Trans. SNAME, vol. 79

3. International Chamber of Shipping, Report submitted to IMCO Subcommittee DE, February, 1971

4. IMCO DE/27, London, 6 May 1970

5. "Operational Research and Cost Benefit Analysis on Navigation with Particular Reference to Marine Accidents", Journal of the Institute of Navigation, vol. 23, No. 3, July, 1970

APPENDIX A

SHIP DATA TABLES

TABLE A-1 Principal Characteristics

Design	LBP meters	Beam meters	Depth meters	Draft meters	SHP	Speed knots
120-A	259.1	42.1	20.7	15.8	26,000	16.2
120-C	259.1	42.1	26.2	15.8	26,000	16.2
250-A	330.7	51.8	25.6	19.9	32,000	16.0
250-A IMCO	330.7	51.8	25.6	19.9	32,000	16.0
250-B1	330.7	51.8	28.0	19.9	32,000	16.0
250-B2	330.7	51.8	29.6	19.9	32,000	16.0
250-C	330.7	51.8	32.2	19.9	32,000	16.0
250-D	330.7	51.8	31.7	19.9	32,000	16.0
250-E1	330.7	51.8	29.0	19.9	32,000	16.0
250-E2	330.7	51.8	31.7	19.9	32,000	16.0
500-A	360.0	62.0	36.0	28.0	45,000	14.6
500-E1	360.0	62.0	40.7	28.0	45,000	14.6

TABLE A-2 Capacities

Design	Deadweight Long Tons	Cargo Oil m^3 (100%)	Segregated Ballast Long Tons S.W. (100%)	Segregated Ballast % of DWT
120-A	124,379	151,000	24,200	19.5
120-C	116,383	152,000	68,000	58.4
250-A	249,360	312,000	42,000	16.0
250-A IMCO	248,990	312,000	40,000	16.1
250-B1	244,216	307,000	72,500	29.6
250-B2	243,070	310,000	99,700	41.0
250-C	237,508	312,000	132,200	55.8
250-D	241,288	312,000	133,600	55.4
250-E1	246,711	311,000	93,400	37.8
250-E2	241,876	316,000	132,900	55.0
500-A	474,062	585,000	75,500	15.9
500-E1	463,264	584,000	170,000	36.7

Design	Displacement long Tons
120	145,270
250	286,600
500	539,400

TABLE A-3 Light Ship Weight in Tons

Design	Ordinary Strength Steel	H.T.S. Type AH & DH	Outfit	Machinery	Margin 3%	Light Ship
120-A	11,699	5,273	2,196	1,115	608	20,891
120-C	22,275	2,174	2,467	1,130	841	28,887
250-A	20,520	10,880	3,595	1,160	1,085	37,240
250-A IMCO	20,779	10,880	3,696	1,160	1,095	37,610
250-B1	28,360	8,230	3,400	1,160	1,234	42,384
250-B2	29,586	7,947	3,546	1,183	1,268	43,530
250-C	35,919	6,682	3,863	1,198	1,430	49,092
250-D	29,884	9,116	3,794	1,198	1,320	45,312
250-E1	24,309	9,424	3,811	1,183	1,162	39,889
250-E2	30,037	8,361	3,840	1,183	1,303	44,724
500-A	45,039	11,883	5,013	1,500	1,903	65,338
500-E1	56,013	11,066	5,289	1,550	2,218	76,136

TABLE A-4 Longitudinal Strength Summary

Design	Condition of Maximum Bending Moment	Bending Moment foot-tons	Shear Force tons
120-A	60% ballast	498,000	4,200
120-C	60% ballast	721,000	4,200
250-A	100%	2,152,000	11,400
250-A IMCO	100%	2,152,000	11,400
250-B1	100%	2,117,000	11,300
250-B2	45% ballast	2,130,000	13,700
250-C	45% ballast	1,882,000	11,200
250-D	100%	2,009,000	9,300
250-E1	60% ballast	2,035,000	15,200
250-E2	60% ballast	1,965,000	13,900
500-A	100%	3,179,000	19,000
500-E1	100%	2,616,000	14,800

TABLE A-5 Damage Stability Summary

Design	Depth ft. (m.)	Available GM-ft. (m.) full load	Required GM to limit heel to 15°-ft. (m.)
120-C	86.0 (25.2)	18.6 (5.7)	8.3 (2.5)
250-A	84.0 (25.6)	27.1 (8.3)	11.2 (3.4)
250-B2	97.0 (29.6)	14.2 (4.3)	6.9 (2.1)
250-C	106.0 (32.3)	10.5 (3.2)	15.3*(4.7)
250-D	104.0 (31.7)	15.7 (4.8)	15.4 (4.7)
250-E2	104.0 (31.7)	16.4 (5.0)	8.1 (2.5)
500-E1	133.5 (40.7)	16.6 (5.1)	6.2 (1.9)

* A GM of 9.3 feet (2.8 m.) limits heel to 21.7° which is less than the 23.3° necessary to immerse the deck edge. This design was therefore deemed satisfactory, since it does not immerse the deck edge.

TABLE A-6 Total Internal Tankage Area Requiring Special Coating

Design	Area m^2	Area ft^2
120-A	79,800	859,000
120-C	107,400	1,156,000
250-A	95,700	1,030,000
250-A IMCO	111,500	1,200,000
250-B1	118,100	1,271,000
250-B2	140,000	1,507,000
250-C	166,700	1,794,000
250-D	174,400	1,877,000
250-E1	142,400	1,533,000
250-E2	160,900	1,732,000
500-A	142,400	1,533,000
500-E1	206,000	2,217,000

TABLE A7

SUMMARY OF SHIPBUILDING PRICES FOR TWELVE TANKER DESIGNS

(IN DOLLARS)

	PRICE DIFFERENCE CATEGORIES	250-A	250-A I.MCO	250-B1	250-B2	250-C	250-D	250-E1	250-E2	120-A	120-C	500-A	500-E1
1	STEEL	-	107,000	2,576,000	2,952,000	5,551,000	3,211,000	1,031,000	2,869,000		3,522,000		4,359,000
2	COATINGS & PAINT	-	198,000	296,000	580,000	931,000	1,625,000	607,000	855,000	-	372,000	-	829,000
3	CARGO OIL STRIPPING & BALLAST PIPING	-	85,000	(-137,000)	18,000	316,000	94,000	214,000	223,000	-	544,000	-	319,000
3A	BALLAST PUMP	-	-	-	84,000	84,000	84,000	84,000	84,000	-	61,000	-	105,000
4	ANCHORS & CHAIN	-	-	-	35,000	82,000	35,000	35,000	35,000	-	45,000	-	26,000
5	MANHOLES, HATCHES & SPLIT GRATINGS	-	(-8,000)	5,000	(-2,000)	24,000	15,000	(-8,000)	(-9,000)	-	26,000	-	(-7,000)
6	VERTICAL & INCLINED LADDERS	-	7,000	6,000	7,000	10,000	8,000	14,000	20,000	-	12,000	-	13,000
7	PRICE INCREMENT & % INCREASE OVER BASE	-	389,000 (0%)	2,746,000 (6.2%)	3,674,000 (8.7%)	6,998,000 (17.5%)	4,472,000 (10.8%)	1,977,000 (4.2%)	4,077,000 (9.8%)	-	4,582,000 (22.8%)	-	5,844,000 (9.0%)
8	1974 DELIVERY PRICE - Millions AT + 308 $	37.3M	37.7	40.1	41.0	44.3	41.8	39.3	41.4	20.1	24.7	65.0	70.8M

APPENDIX B

ECONOMIC BASES

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I Operational Factors

A. Increased Pumpout

Double bottom ships receive a credit for increased pumpout as follows:

120-C	675 tons per voyage
250-B1, 250-B2, 250 C	1100 tons per voyage

B. Faster Pumpout

All double bottom ships have port time per round trip decreased by 2 hours

C. Berthing Costs

Delays are assumed to be a function of freeboard in loaded condition. Also, it is assumed that the ship with the greatest freeboard encounters a delay of 4-1/2 hours once in 10 trips

Ship	Hours Delay/10 Trips
250-A IMCO	0.0
250-B1	1.6
250-B2	2.7
250-C	4.5
250-D	4.1
250-E1	2.3
250-E2	4.2
120-A	0.0
120-C	4.5
500-A	0.0
500-E1	2.3

D. Reduced Tank Cleaning

1. Cleaning for Ballast

Assume base ships clean 1/3 of vessel each trip

(33 man-days/voy. for 250-A IMCO

2. Cleaning between Drydockings

Each complete cleaning requires --

100 man-days for 250 class

75 " " 120 "

150 " " 500 "

Assuming 8 trips between drydockings for the long voyage, this would mean 2 complete cleanings for single bottom vessels, minus those tanks cleaned for ballast. For double bottom vessels, once between d.d.

Version	# Complete cleanings x man-days	# Man-days
250 - IMCO	2(1 - 1/3) x 100 man-days	133
250-A	2(1 - 1/3) x " "	133
B1	1(1 - 1/4) x " "	75
B2	1(1 - 1/10)x " "	90
C	1(1 - 0) x " "	100
D	2(1 - 0) x " "	200
E1	2(1 - 1/10)x " "	180
E2	2(1 - 0) x " "	200
F	1(1 - 0) x " "	100
120-A	2(1 - 1/3) x 75	100
120-C	1(1 - 0) x "	75
500-A	2(1 - 1/3) x 150	200
500-E1	2(1 - 0) x "	300

3. Cleaning for Drydocking

Assume: 1 day of cleaning = 10 man-days

250 class double bottom vessels save 2 days*

250 class double skin vessels save 2-1/2 days*

*This is a labor savings only and is not reflected in an increase in ship operating time. See Subsection IV D, Sensitivities, for effect of changing operating days.

II Maintenance and Repair

The basic maintenance and repair costs given in Table 1 are varied to account for changes in the annual tank coating maintenance cost which is considered to be a function of the total coated area on each design or:

= (Area repaired per year) x (Cost per unit area)

= .025 x Total Coated Area x $\$1.25/ft^2$

Version	Area	M&R Cost $	Incremental Cost $
250-A	1,030,197	32,194	---
250-A IMCO	1,199,919	37,494	5,303
250-B1	1,271,087	39,721	7,528
250-B2	1,507,327	47,104	14,910
250-C	1,793,857	56,058	23,864
250-D	1,877,007	58,656	26,463
250-E1	1,533,329	47,917	15,723
250-E2	1,731,773	54,118	21,925
120-A	858,649	26,823	---
120-C	1,156,160	36,130	9,297
500-A	1,533,196	47,912	---
500-E1	2,217,289	69,290	21,377

III Port Charges

Assumptions

1. Port Charges are assumed to be a function of gross tonnage
2. For the vessels in this study, gross tonnage is a function of depth

Version	Depth	Port Charges
250-A, 250-A IMCO	84 ft.	51,000
B1	92	56,000
B2	97	58,900
C	106	64,400
D	104	63,100

Version	Depth	Port Charges
250-E1	95 ft.	57,700
E2	104	63,100
120-A	68	24,000
C	86	30,400
500-A	118	98,000
E1	133.5	110,900

Added costs incurred because of larger sail areas (primarily tug costs) have not been quantified. However, the assumption that GRT is a linear function of depth penalizes the deeper vessels and, at least in part, compensates for the added costs which are too uncertain to be reasonably estimated.

IV Insurance

Insurance cost is determined through the use of the following equation:

$$\text{Premium} = 0.905\ ((F_1 \text{xDwt}) + F_2\text{x(Capital Cost)} + F_3) + F_4$$

where:

	120 Series	250 Series	500 Series
F_1	3.55	4.480	5.480
F_2	.00629375	.007725	.007725
F_3	-59,000	-225,000	-575,000
F_4	2,000	10,000	10,000

Version	Premium (M$)
250-A IMCO	1079.4
A	1078.9
B1	1076.9
B2	1078.5
C	1079.0
D	1077.5
E1	1081.1
E2	1078.5
120-A	463.3
C	463.7
500-A	2295.1
E1	2282.1

It should be noted that use of this equation indicates little difference in premium among the various designs in each series. This occurs since the major portion of the premium is to provide coverage against partial loss to the ship and this is a function of deadweight rather than capital cost. Since the alternatives to the base case have lower deadweight than the base case ships, they will have a lower premium for protection against partial loss. This factor weighs against the increased premium for protection for total loss which is a function of initial capital cost.

While this formula is considered representative of present practice, it is expected that if segregated ballast ships, particularly with such features as double skins, etc. come into general use, their insurance premiums will depend more strongly on capital cost and less on deadweight than is shown in this study.

APPENDIX C

PLANS

(NOT ENCLOSED)

ANNEX III

AN ANALYSIS OF OIL OUTFLOW

DUE TO TANKER ACCIDENTS

Submitted to the

IMCO Subcommittee on Ship Design and Equipment

and the

IMCO Subcommittee on Marine Pollution

in

November 1972

AN ANALYSIS OF OIL OUTFLOWS DUE TO TANKER ACCIDENTS

A NOTE BY THE
UNITED STATES OF AMERICA

An Analysis of Oil Outflows Due to Tanker Accidents

A Note by the United States of America

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Executive Summary

This note presents an analysis of the reported and estimated amounts of oil that enter the world's hydrological system each year as a result of tanker casualties. (It does not consider such tanker related pollution sources as burst hoses, leaky valves, tank overflows, etc.). This analysis is primarily based upon data for the years 1969 and 1970, together with a limited comparison with available data from other years to ensure the general validity of the two-year data.

The data considers the 1,416 tanker casualties and 266 tanker polluting incidents known to have occurred in 1969 and 1970 to the approximately 6,000 tankers of 100 GRT and over then in operation. Actual outflow data was gathered on 47 percent of the 266 tanker polluting incidents known to have occurred in the two-year period. The outflow from the remaining incidents was calculated by assuming them to be non-catastrophic and then averaging the magnitude of outflows for each of the types of casualties with known outflows of 500 long tons or less.

The principal findings of the analyses are:

- every tanker on the average is likely to be involved in an accident once every nine years during its lifetime;
- approximately one out of every six of these casualties (133 per year) is likely to result in a polluting incident; or one out of three tankers is likely to be involved in a polluting incident during its 20 year life;

- the average annual outflow from all tanker casualties is approximately 218,000 metric tons;
- approximately 12 percent of the polluting incidents account for three quarters of the total outflow. This 12 percent is comprised of structural failures, groundings, and explosions involving the total loss of the tanker. An important conclusion to draw from here is that incidents involving the total loss of the tanker have a distinct effect upon the analysis;
- the single largest type of tanker casualty in causing pollution is structural failures. Ten structural failures involving tankers with an average age of 17 years and an average size of 27,443 DWT, resulted in the total loss of the vessel and 48 percent of the total outflow in 1969 and 1970;
- the next largest type of tanker casualty in causing pollution is groundings. Outflows from groundings exceed those from collisions by a factor of 4.25. This is with an equal frequency of occurrence of either type of casualty. Groundings accounted for 29 percent of the total outflow in 1969 and 1970;
- there is no clear indication that there is any relationship among tanker size, casualty frequency and oil outflow magnitude other than in the case of explosions on very large tankers;
- certain flags of registry appear to need higher levels of standards and maintenance; and,

. analysis of tanker pollution data by counting numbers of incidents only, without recourse to the amount of outflow, can be misleading.

INTRODUCTION

The concern over pollution of the seas by oil has resulted in the development of numerous proposals for reducing the amount of oil entering the oceans. To evaluate the relative merits of these proposals requires data on the costs involved and their effectiveness in eliminating or mitigating oil spillage. In turn, the determination of this effectiveness requires data on the amounts of oil now entering the sea from the particular source under consideration.

This paper presents an analysis of the amount of oil entering the sea as a result of world-wide tanker casualties (it does not consider such tanker related pollution sources as burst hoses, leaky valves, tank overflows. etc.). The analysis is primarily based upon data for calendar years 1969 and 1970, together with a limited comparison with available data from other years to ensure the general validity of the two-year data.

The paper attempts to determine how much oil enters the sea, both on a total basis and for each of the individual types of casualty, such as grounding, collision, structural failure, etc. As such, these data can form a basis for evaluating many of the various proposals for reducing oil outflows from tanker casualties.

The paper will present and analyze:

. total annual tanker casualty outflow;

. distribution of total annual tanker casualty outflow by location;

. distribution of total annual tanker casualty outflow by ship size; and,

. distribution of total annual tanker casualty outflow by ship age.

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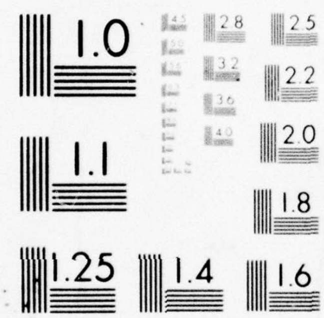

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Data and Method of Analysis

Within the past two years, several estimates of oil pollution from tanker casualties have been presented [1,2,3,4][1]. These vary from approximately 50,000 long tons per year for all tankers greater than 7,000 DWT [4] to 250,000 metric tons per year for all tankers [3]. One of the other sources cites a figure of 100,000 long tons per year for all types of ships [2]. Apart from this large variance in ranges, only one source has attempted to assess the contribution of the different types of casualties to the total outflow[4].

Reference 3 identified a total of 1,416 tanker casualties that occurred in calendar years 1969 and 1970. The data further indicated that some pollution occurred in at least 269 of these incidents. Two-hundred and sixty-six of these incidents have formed the basis for this analysis. To determine the amount of oil outflow related to each of these incidents the following sources were used:

- Internal data on oil company owned and chartered tankers involved in polluting incidents during 1969 and 1970;
- Published data which provided details of individual incidents [5,6,7]; and,
- Newspapers, magazines, etc. for details of particular data.

In 110 of the incidents, actual outflow data was tabulated including 47 which recorded as minimal outflows and are shown as 1 long ton for computation purposes. In 14 instances, available data gave a description of damage but not oil outflow; here, an estimate of the oil outflow was made based on the damage

[1] Numbers in brackets designate references at end of paper.

Table 1. Sensitivity of Calculated Outflow to Averaging Technique

Type of Incident	Calculated Outflow Using 500T or Less	Calculated Outflow Using 1000T or Less
Breakdown	25T	25T
Collision	102T	225T
Explosion	72T	72T
Fire	76T	360T
Grounding	90T	193T
Ramming	18T	158T
Structural Failure	40T	40T
Others	213T	213T
Total Calculated Outflow	10,457T	19,485T

description and cargo condition. Where a fully loaded tanker sank, a reported outflow equal to the vessel's cargo capacity was recorded; where a tanker in ballast sank, an estimated outflow equal to the vessel's bunker capacity was recorded.

In the remaining 142 incidents where neither outflow data nor sufficient damage details were available, it was assumed that none of these incidents were greater than 500 long tons. It then followed for any one given type of casualty (e.g. groundings, collisions, etc.) if one took the average known outflow for all incidents within that type of casualty of 500 tons or less, these could then be assigned to the remaining 142 incidents on a casualty type basis.

Table 1 depicts the calculated values for outflows based on using: (1) all known incidents of 500 tons or less; and (2) all known incidents of 1,000 tons or less.

In terms of the total outflow over the two-year period in the 500 ton case, this gave 430,720 long tons whereas the 1,000 ton case gave a total of 439,748 long tons. Overall then, it can be said that the total outflow is insensitive to the averaging technique. In fact if all 142 calculated outflows are reduced to zero the total outflow is 420,263 long tons. For the purposes of analysis, however, the 500 ton case figures will be employed throughout this paper. Table 2 depicts the total oil outflow spectrum on a casualty type basis.

Table 2. 1969-1970 Tanker Polluting Incident Frequency and Outflow Magnitude as a Function of Type of Casualty and the Method of Determining the Amount of Outflow

Type of Casualty	Reported	Estimated	Minimum	Calculated[2]	Total
Breakdown	16,350(1)[3]	0(0)	0(0)	50(2)	16,400(3)
Collision	16,116(17)	13,348(5)	13(13)	4,794(47)	34,271(82)
Explosion	15,524(3)	18,300(3)	6(6)	216(3)	34,046(15)
Fire	2,154(3)	1,250(1)	3(3)	912(12)	4,319(19)
Grounding	119,906(22)	1,400(2)	16(16)	2,700(30)	124,022(70)
Ramming	2,800(3)	1,600(1)	5(5)	252(14)	4,657(23)
Structural Failure	206,553(13)	4,490(1)	4(4)	1,320(33)	212,367(51)
Other	400(1)	25(1)	0(0)	213(1)	638(3)
Column Totals	379,803(63)	40,413(14)	47(47)	10,457(142)	430,720(266)[4]

[2] Based on averaging known incidents of 500 tons or less.

[3] Incident was a mechanical breakdown which led to a subsequent grounding and eventual break-up of the tanker.

[4] Equivalent to 437,612 metric tons of outflow in the two-year period.

Casualty Data

Reference 3 compiled data on 1,416 worldwide tanker casualties which resulted in 266 established polluting incidents. The parameters examined during this casualty analysis include: The tanker's name, country of registry, tonnage, year built, cargo condition, type and date of casualty, degree of damage, amount of oil outflow,the method of determing that outflow, and geographical location with a detailed area of the casualty.

The casualty types are: groundings, collisions, (ship to ship casualty), rammings (ship to object casualty), fires, explosions, structural failures (including heavy weather damage), mechanical breakdowns, and the group termed "other casualties". The "other casualties" include tanker capsizings and a tanker sinking at the pier due to a faulty valve and the subsequent flooding of the engineroom. When the initial casualty led to a second, such as a mechanical breakdown resulting in a subsequent grounding, only the initial casualty was counted among the total casualties.

Analysis by Type of Incident

As shown in Table 2 and Figures 1 and 2, an analysis conducted solely on incident frequency basis can be misleading if the attendant outflows are not simultaneously considered. For example, if one computes the ratio of number of groundings to number of collisions, a figure of 0.85 is established. On the other hand, the ratio of oil outflow from groundings to collisions is 3.62. These data say that the probability of being involved in a collision is approximately 16 percent higher than that of being involved in a grounding. The average oil outflow of the 70 groundings is some 1,772 long tons; whereas, the average oil outflow of the 82 collisions is 418 long tons. Comparing these average computed oil outflows, shows the average grounding outflow 4.25 times greater than the average collision outflow. Recognizing that this is contrary to the Intergovernmental Maritime Consultative Organization (IMCO) hypothetical outflows of 4 and 3 to 1 in favor of collisions, the following factors which substantiate the ratio deduced in this paper should be noted:

- Except for some rather small tankers, no collisions resulted in the total loss of a loaded vessel. Such was not the case with groundings; five[5] tankers which grounded subsequently broke up and sunk with a total outflow of 78,109 tons.[6]

[5] Includes case 037 which was a mechanical breakdown leading to a subsequent grounding and break-up.

[6] If one discounts these incidents since they are independent of tank size, the ratio of outflows from groundings to collisions is 2.88.

. Many of the groundings involved a multiplicity of tanks (not necessarily consectutive though). For example, in one instance a grounded tanker ruptured port wing tanks number 1, 3, 5, 6, 7, and 9.

Table 3 depicts the cargo condition of the 151 grounding and collision polluting incidents.

In the known conditions, 83.9 percent of the collision incidents were in the loaded condition while 79 percent of the grounding incidents involved a loaded tanker. This says that while there are more collisions involving a loaded tanker than for groundings, the total and "per incident" outflows from groundings exceed those from collisions. In fact, even if one assumed that all the unknown cargo conditions for collisions (26) were the "in ballast" case and all the unknown cargo conditions for groundings (8) were "loaded", 57.3 percent of the collisions and 77.1 percent of the groundings involved loaded tankers. Transmitting this to the grounding outflow to collision per incident outflow ratio of 4.25, it would reduce this ratio to 3.13. In other words, there are no significant differences in cargo conditions between groundings and collisions that would tend to alter the great disparity between grounding and collision outflows.

The only way that the data could be sorted to have a greater collision outflow than grounding outflow, was to consider only those incidents with an outflow of less than 1,000 long tons. In this instance, the outflow ratio of groundings to collisions is 0.82. It is not felt, however, that this case has any significant meaning.

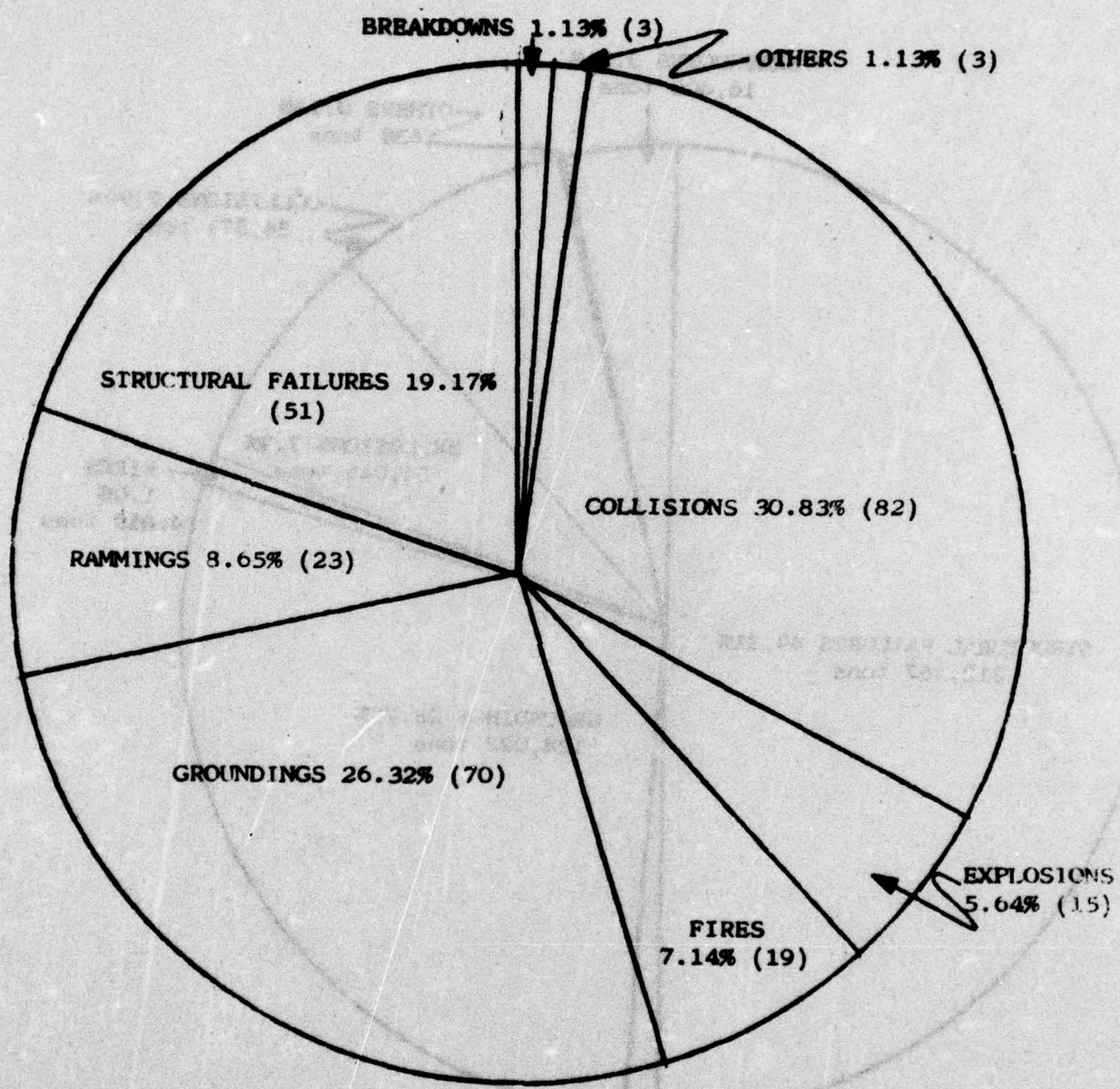

Figure 1 266 Polluting Incidents - Frequency Distribution

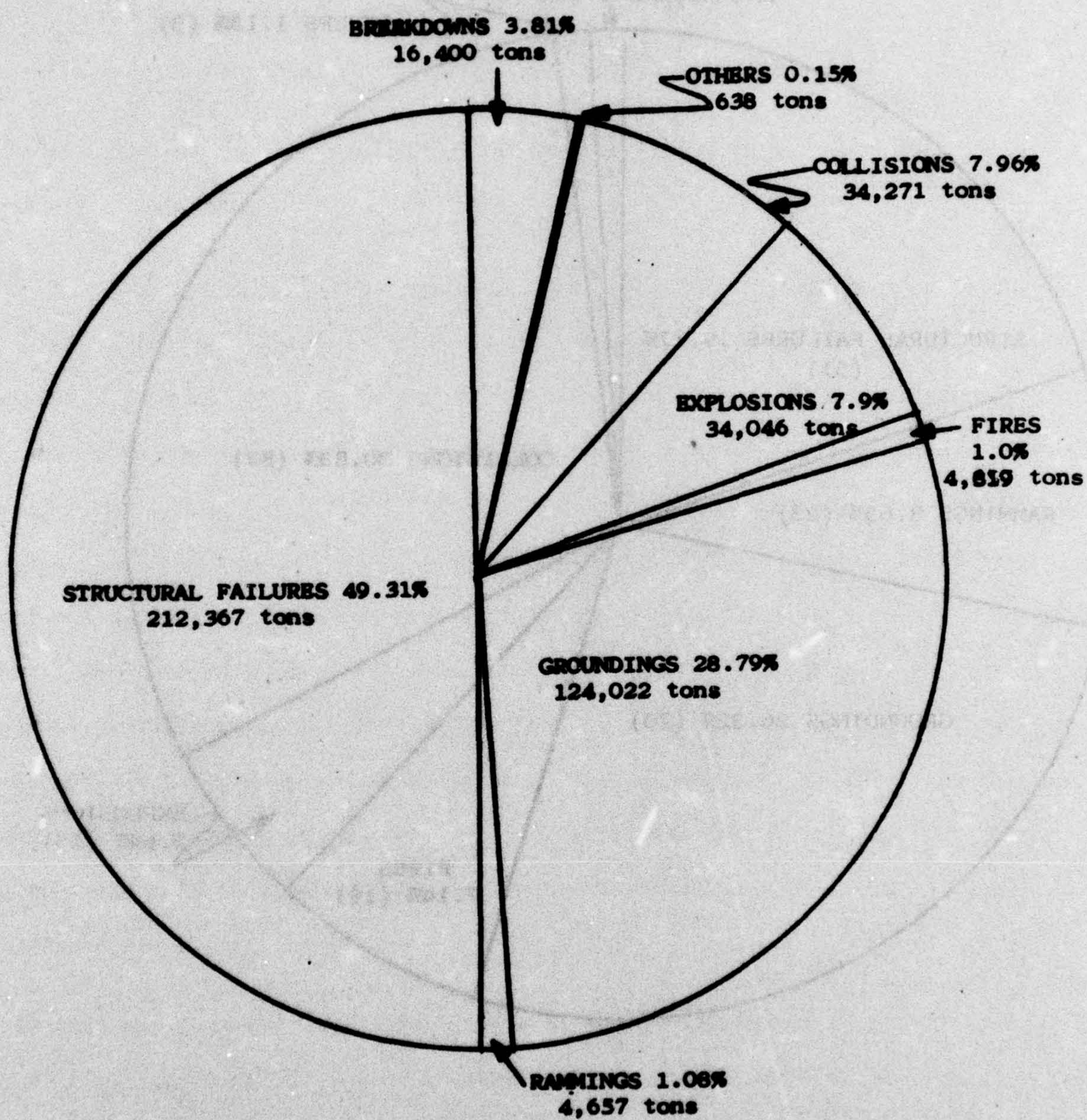

Figure 2 266 Polluting Incidents and 430,720 Long Tons of Outflow - Magnitude Distribution

Table 3. Cargo Condition of Collision and Grounding Polluting Incidents

	Loaded	Loaded With Other Than Persistent Oil	In Ballast	Unknown Cargo Condition
Collisions (82)	42	5	9	26
Groundings (70)	48	1	13	8
Total (152)	90	6	22	34

Table 4. Comparison of Relative Oil Outflows from Groundings and Collisions

	FRENCH DATA		U. S. DATA	
	Total	Excluding Total Losses	Total	Excluding Total Losses
Ratio of total outflows, groundings to collision	3.94	2.13	3.62	2.50
Ratio of outflow, grounding to collision on per incident basis	2.56	1.60	4.26	2.88

A comparison of the data contained herein regarding collisions and groundings with reference 4 is shown in Table 4.

Two other types of casualty also warrant some detail; namely explosions and structural failures.

Explosions

Appendix I shows 15 tanker explosions. Of these, six occurred during a loaded condition. In the six cases where the tanker had oil aboard, five explosions occurred at the pier during a cargo transfer operation. Seven of the nine explosions which occurred with the tanker in ballast took place at sea; one of the remaining ones occurred in a coastal zone and the final one occurred in an unknown location. At least five of the explosions which occurred in the ballast condition took place during tank cleaning. Not a single tanker equipped with an inerting system is recorded among the entire list of tanker with cargo tank explosions. On a non-dimensional basis the data clearly show that there is a more significant explosion problem on large tankers (greater than 80,000 DWT) than on the remainder of the tanker fleet (5.51 as opposed to 0.71).

Structural Failures

Fifty-one structural failures accounted for 212,367 long tons or 49.3 percent of the total oil outflow in the two-year data base. Ten of them, in the loaded condition, with an average age of 17 year and average size of 27,443 tons sunk and contributed 206,278 long tons of that oil outflow.

Impact of Total Losses

The impact of total losses upon the frequency and magnitude of tanker casualties is shown in Table 5. This table shows the resultant frequency and magnitude for a given type of casualty when all total tanker losses are excluded. In terms of frequency, no appreciable differences are seen, however, the outflows are significantly changed; especially explosions and structural failures. Whereas these were eight and forty-nine percent, respectively, they are now one and seven percent. Groundings become the predominant outflow cause at 62 percent with collisions next at 25 percent.

The overall ratio of grounding outflow to collisions outflow changes to 2.5 and on a per incident basis to 2.88. In this respect, grounding outflows still exceed collision outflows by a factor of approximately 3 to 1 in lieu of a 4 to 1 ratio, previously calculated, using the entire 266 polluting incidents. While total losses result in only about 13.7 percent of the polluting incidents, their attendant outflows represent 27.4 percent of the total collision pollution, nearly 50 percent of the total grounding pollution, 98 percent of the explosion, and 97 percent of the structural failure pollution. Overall their total outflows represent 76.5 percent of the 430,720 long ton outflow figure. Thus it appears that the occurrence of total losses and the ability of a tanker to survive a catastrophic casualty must also be considered.

Table 5. Impact of Total Losses Upon Frequency and Magnitude of Casualties[7]

	Number of Incidents	Percent of Total Incidents	Outflow	Percent of Total Outflow
Breakdowns	2	0.85	50	0.05
Collisions	76	32.48	24,877	24.60
Explosions	10	4.27	722	0.71
Fires	16	6.84	1,215	1.20
Groundings	66	28.21	62,263	61.58
Rammings	23	9.83	4,657	4.61
Structural Failure	40	17.09	7,114	7.04
Others	1	0.43	213	0.21
Totals	234	100.0	101,111 Tons	100.0

7 The numbers in this table exclude all incidents involving the total loss of a tanker.

Analysis by Deadweight

An attempt was made to show what, if any, correlation exists between accident frequency, incident outflow, and tanker size. Table 6 shows for various deadweight ranges, the average number of vessels in that category operating during the two-year sampling period, the number of polluting incidents, and the total outflow from those incidents. The table then non-dimensionalizes frequency and magnitude on both the basis of number of tankers and total deadweight in a given range. The four non-dimensional parameters are as follows:

. A/B - the number of incidents in a given range divided by the number of tankers in the same range;

. C/B - the total outflow from the incidents in a given range divided by the number of tankers in the same range;

. A/D - the number of incidents in a given range divided by the total deadweight in the same range; and,

. C/D - the total outflow from the incidents in a given range divided by the total deadweight in the same range.

A number other than one says:

. for A/B, there is a smaller or larger frequency of casualties for the number of vessels in that range;

. for A/D, there is a smaller or larger frequency of casualties for the deadweight represented in that range,

. For C/B, there is a smaller or larger oil outflow magnitude from casualties for the number of vessels in that range; and,

. for C/D, there is a smaller or larger oil outflow magnitude from casualties

Table 6A. Distribution of the World Tanker Fleet as a Function of Deadweight During the 1969-1970 Period[8]

Deadweight Range	Number of Tankers	(B) Percent of Total Tankers	Representative Deadweight	(D) Percent of Total Deadweight
To 10,000	2,609	43.83	4,005,557	2.95
10,000-19,999	1,208	20.29	20,064,280	14.78
20,000-29,999	585	9.83	14,163,340	10.43
30,000-39,999	447	7.51	15,358,680	11.31
40,000-49,999	296	4.97	13,465,060	9.92
50,000-59,999	208	3.49	11,231,780	8.27
60,000-69,999	146	2.45	9,563,720	7.04
70,000-79,999	136	2.28	10,116.140	7.45
80,000-89,999	86	1.45	7,348,460	5.41
90,000-99,999	78	1.31	7,423,500	5.47
100,000-149,999	95	1.60	10,856,640	8.00
150,000-199,999	19	0.32	3,160,780	2.32
200,000 Upwards	40	0.67	8,937,560	6.58
	5,953	100.0	135,695,497	100.0

8 The number of tankers and representative deadweight in any one range is the weighted average of tankers 100 GRT and upwards on record with Lloyds as of 1 January 1969 and 31 December 1970. To compensate for actual days of operation from the first carriage of a cargo of oil, all tankers delivered in the 2-year interval are weight averaged over a 5-month period whereas all existing tankers as of 1 January 1969 are weight averaged over the full 24-month period.

Table 6B. Distribution of the 266 Incidents and Outflows as a Function of Deadweight During the 1969-1970 Period

Deadweight Range	Number of Incidents	(A) Percent of Total Incidents	Outflow in Range	(C) Percent of Total Outflow
To 10,000	63	23.69	10,939	2.54
10,000-19,999	75	28.20	155,966	36.21
20,000-29,999	41	15.41	45,924	10.66
30,000-39,999	22	8.27	94,356	21.91
40,000-49,999	14	5.26	54,825	12.73
50,000-59,999	11	4.14	20,604	4.78
60,000-69,999	9	3.38	6,467	1.50
70,000-79,999	10	3.76	14,174	3.29
80,000-89,999	4	1.50	82	0.02
90,000-99,999	3	1.13	5,891	1.37
100,000-149,999	3	1.13	8,002	1.86
150,000-199,999	1	0.38	102	0.02
200,000 Upwards	10	3.76	13,388	3.11
	266	100.0	430,720	100.0

Table 6C. Non-Dimensional Analysis of the 266 Incidents and Outflows as a Function of Deadweight During the 1969-1970 Period

Deadweight Range	A/B	A/D	C/B	C/D
To 10,000	0.49	8.03	0.05	0.86
10,000-19,999	1.39	1.91	1.78	2.45
20,000-29,999	1.57	1.48	1.08	1.02
30,000-39,999	1.10	0.73	2.92	1.94
40,000-49,999	1.06	0.53	2.56	1.28
50,000-59,999	1.19	0.50	1.37	0.58
60,000-69,999	1.38	0.48	0.61	0.21
70,000-79,999	1.65	0.51	1.44	0.44
80,000-89,999	1.03	0.28	0.01	0.002
90,000-99,999	0.86	0.21	1.05	0.25
100,000-149,999	0.71	0.14	1.16	0.23
150,000-199,999	1.19	0.16	0.06	0.01
200,000 Upwards	5.61	0.57	4.64	0.47

for the deadweight represented in that range.

A number equal to 1 says of course that the frequency or magnitude, as the case might be, is directly proportional to the denominator; i.e., either number of tankers or deadweight.

The important points to draw from Table 6 are:

- Overall the 10,000-19,999 dwt range shows the highest frequency and magnitude of polluting incidents;
- Tankers over 200,000 dwt have the highest frequency and magnitude when non-dimensionalized to the number of vessels in that class[9] (A/B and C/B); when non-dimensionalized to representative deadweight, however, they are far below the norm;
- The 30,000-49,999 dwt range has the highest outflow on a representative deadweight basis (C/D).

[9] This is due to the small number of vessels in that range and 3 major tank explosions which sunk one vessel.

Analysis of Structural Failures by Vessel Age

Figure 3 and Table 7 show the frequency and magnitude of polluting incidents as a function of tanker age normalized to the number and total deadweight of tankers in any one age group. The four non-dimensional numbers A/B, C/B, A/D, and C/D are similar to those described previously. The important points to note is as follows:

. Overall, tankers built between 1946 and 1955 shown the worst frequency and oil outflow magnitude record; and as previously stated ten tankers with an average age of 17 years sunk and contributed 206,278 long tons of oil outflow.

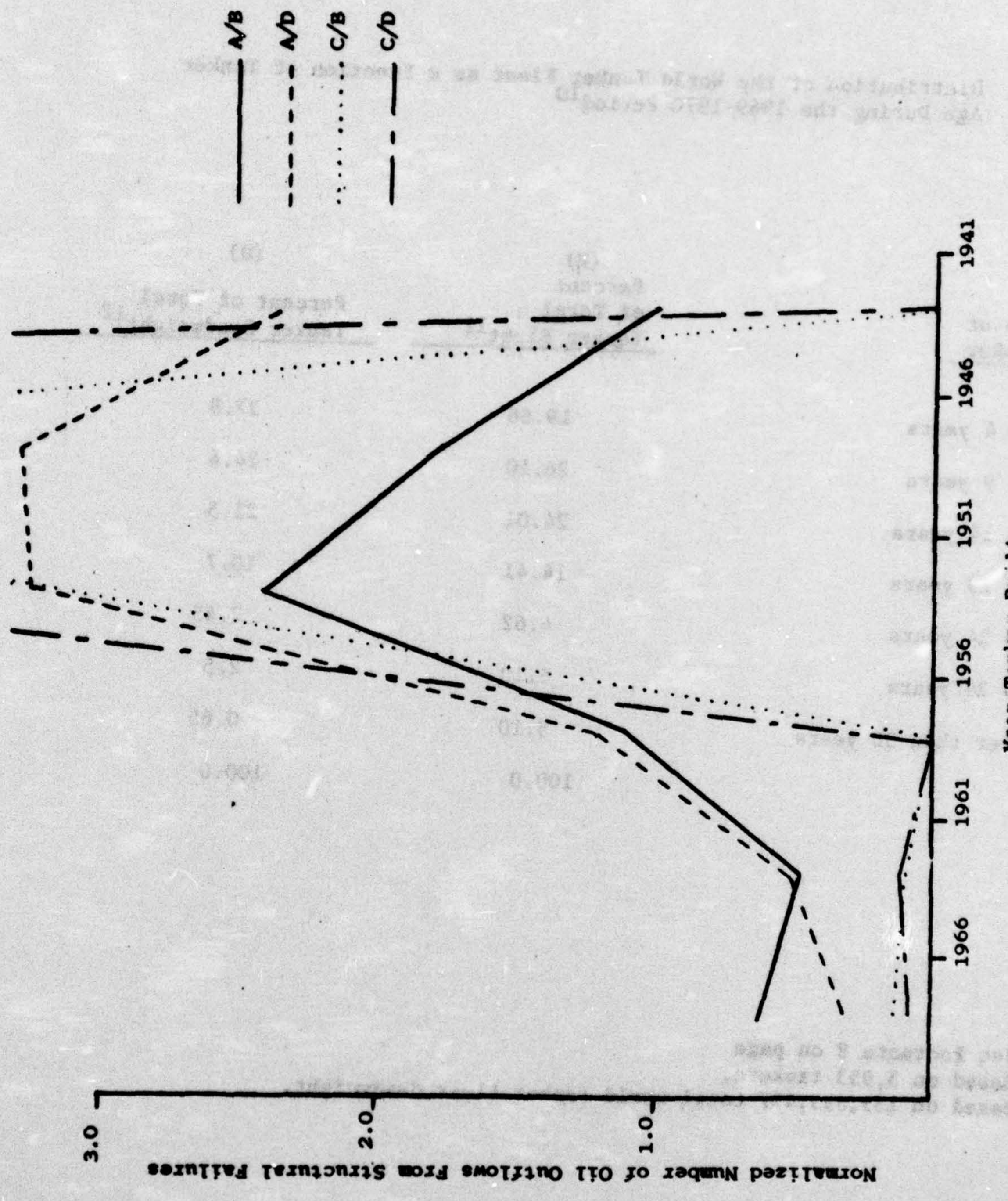

Figure 3   Tanker Age vs. 49 Structural Failures in 1969 and 1970

Table 7A. Distribution of the World Tanker Fleet as a Function of Tanker Age During the 1969-1970 Period[10]

Age of Tanker	(B) Percent of Total Tanker Fleet[11]	(D) Percent of Total Tanker Deadweight[12]
0 to 4 years	19.66	37.8
5 to 9 years	26.10	24.4
10 to 14 years	24.01	21.5
15 to 19 years	14.41	10.7
20 to 24 years	4.62	.2.45
25 to 29 years	6.10	2.5
Greater than 30 years	5.10	0.65
	100.0	100.0

[10] See footnote 8 on page

[11] Based on 5,953 tankers.

[12] Based on 135,695,497 total world tanker fleet deadweight.

Table 7B. Distribution of the 49[13] Structural Failures and their Outflows as a Function of Tanker Age During the 1969-1970 Period

Age of Tanker	Number of Structural Failures	(A) Percent of Total Structural Failures	Outflow in Range	(C) Percent of Total Outflow
0 to 4 years	6	12.25	5,802	3.02
5 to 9 years	6	12.25	4,690	2.44
10 to 14 years	13	26.53	567	0.30
15 to 19 years	17	34.69	102,356	53.34
20 to 24 years	4	8.16	78,422	40.86
25 to 29 years	3	6.12	90	0.04
Greater than 30 years	0	0	0	0
	49	100.0	191,927	100.0

[13] Two structural failures with a total outflow of 20,440 long tons are excluded from this analysis since the age of the two tankers in question was indeterminate.

Table 7C. **Non-Dimensional Analysis of 49 Structural Failures and Their Outflows as a Function of Tanker Age During the 1969-1970 Period**

Age of Tanker	A/B	A/D	C/B	C/D
0 to 4 years	0.62	0.32	0.15	0.08
5 to 9 years	0.47	0.50	0.09	0.10
10 to 14 years	1.11	1.23	0.01	0.02
15 to 19 years	2.41	3.24	3.70	4.99
20 to 24 years	1.77	3.26	8.85	16.34
25 to 29 years	1.00	2.35	0.01	0.016
Greater than 30 years	0	0	0	0

Analysis by Geographical Location

Table 8 shows the two digit coding employed for the geographical location of the tanker at the time of the casualty. Table 9 shows the frequency and magnitude spectrum for the following selected geographical areas:

. 01 - North West Atlantic Ocean (North of the Tropic of Cancer, between 30° West and the East Coast of the U. S. and Canada);

. 02 - North East Atlantic Ocean (North of the Tropic of Cancer, between 30° West and the West Coast of Europe including the Denmark Strait and Greenland Sea);

. 21 - North West Pacific Ocean (North of the Tropic of Cancer and between the 180th meridian and the Coast of Asia including the sea of Okhotsk, the Sea of Japan and the Yellow Sea);

. 50 - The Mediterrean Sea; and

. 12 - The East Indian Ocean (North of the Tropic of Capricorn and between 20° and 70° East longitude including the Arabian Sea, the Gulf of Aden, and the Red Sea.

These data simply state that at least on a macroscopic view, tanker accidents and oil outflow are a direct function of tanker traffic density; i.e., the accidents occur where the tanker traffic is the densest such as in the Persian Gulf, Northern Europe, Japan, etc..

Table 8. Coding for Location of Ship at the Time of the Casualty

00	Atlantic	
01	North West Atlantic	(North of the Tropic of Cancer, between 30° West and the East Coast of the U. S. and Canada).
02	North East Atlantic	(North of the Tropic of Cancer, between 30° West and the West Coast of Europe - Includes Denmark Strait and Greenland Sea).
03	Middle Atlantic Ocean	(Between the Tropic of Cancer and the Equator, and between South American and the West Indies and the African Coast).
04	Middle Atlantic Ocean	(Between the Tropic of Capricorn and the Equator, and between South American and the African Coast).
05	South West Atlantic	(South of the Tropic of Capricorn and between 30° West and the coast of South American - Includes the Drake Strait).
06	South East Atlantic	(South of the Tropic of Capricorn and between 30° West and the African Coast and 20° East).
07	Carribean Sea and Gulk of Mexico.	
08	Gulf of St. Lawrence and Great Lakes.	
09	Davis Straits, Hudson Bay, and Bulfin Bay	
10	Indian Ocean	
11	Indian Ocean	(South of the Tropic of Capricorn, and between 20° East and 140° East).
12	East Indian Ocean	(North of the Tropic of Capricorn, and between 20° East and 70° East - Includes Arabian Sea, Gulf of Aden, and Red Sea).
13	West Indian Ocean	(North of the Tropic of Capricorn, and between 70° East and 140° East - Includes Bengal Bay and other small bodies among the Malaya Archipelago).
20	Pacific Ocean	
21	North West Pacific	(North of the Tropic of Cancer, and between the 180° Meridian and the coast of Asia - Includes Sea of Okhotsk, Sea of Japan, and Yellow Sea).

Table 8. Coding for Location of Ship at the Time of the Casualty--Continued

22	North East Pacific	(North of the Tropic of Cancer, and between the 180° Meridian and the coast of North America - Includes Gulf of Alaska and Bering Strait).
23	Middle Pacific Ocean	(North of the Equator and South of the Tropic of Cancer, between the East Indies and Central and South America).
24	Middle Pacific Ocean	(South of the Equator and North Tropic of Capricorn, between Australia and the South America coast - Includes Coral Sea and other small bodies of water in these limits).
25	South East Pacific	(South of the Tropic of Capricorn, between 70° West and 180° Meridian - Includes the Tasman Sea).
26	South West Pacific	(South of the Tropic of Capricorn, between 140° East and the 180° Meridian)
30	Artic Ocean	
40	Antartic Ocean	
50	Mediterrean Sea	

Table 9. Frequency and Magnitude of Tanker Polluting Incidents as Function or Geographical Location

	Number of Incidents	Total Outflow
Northwest Atlantic Ocean (01)	35	93,049
Northest Atlantic Ocean (02)	78	86,969
Northwest Pacific Ocean (21)	27	26,848
Mediterrean Sea (50)	17	17,400
East Indian Ocean (12)	11	54,163
Subtotal	168	278,429
All other geographical locations	98	152,291
Total	266	430,720 long tons

Analysis by Area

For the purposes of this analysis, areas are defined as follows:

- . Coastal - within 50 nautical miles of any shoreline;
- . Entranceway - entrance to a harbor, bay, river, etc;
- . Harbor - within the confines of harbors, bays, rivers, etc.
- . Pier - at a wharf, pier, dock, quay, etc. with tanker physically moored thereto; and
- . Sea - more than 50 nautical miles from any shoreline.

The intent of this analysis was to show what type of incidents and associated outflows occurred in the various areas.

Table 10 shows the 266 incidents and associated outflows on an area basis. It shows that 207 incidents with an attendant outflow of 185,893 long tons occurs within 50 miles of a shoreline. It also shows that 88 incidents with an attendant outflow of 41,810 long tons occurred either at the pier or within the confines of a harbor.

Table 11 shows on an individual area basis, the frequency and magnitude of different types of casualties. For example, in the coastal area, 54 incidents out of 60 are either groundings or collisions and account for 56,771 long tons of outflow. Other important points to note are as follows:

- . In the entranceways, 28 groundings account for 77,003 long tons of outflow out of a total of 83,286 long tons that were spilled;
- . In the harbors, 16 groundings had an outflow of 11,930 long tons out of a total of 22,651 long tons spilled;

Table 10. Area Location of the 266 Polluting Incidents and Outflows During the 1969-1970 Period

Area	Number of Incidents	Amount of Outflow	Percent of Outflow
Coastal	60	60,797	14.1
Entrance	59	83,286	19.3
Harbor	45	22,651	5.3
Pier	43	19,159	4.5
Sea	52	240,003	55.7
Unknown	7	4,824	1.1
Total	266	430,720	100.0

Table 11. **266 Polluting Incidents and Outflows Shown by Type of Casualty and Area Locations**

	COASTAL		ENTRANCE		HARBOR		PIER		SEA		UNKNOWN	
	No.	Outflow	No.	Outflow	No.	Outflow	No.	Outflow	No.	Outflow	No.	Outflow
BKD	1	25	0	0	0	0	0	0	1	16,350	1	25
COL	29	21,683	24	5,651	19	5,917	6	612	3	306	1	102
EXP	2	3,824	0	0	0	0	6	14,417	6	15,804	1	1
FRE	2	152	1	76	2	1,326	11	2,612	3	153	0	0
GRD	25	35,088	28	77,003	16	11,930	0	0	0	0	1	1
RAM	0	0	2	36	6	3,437	15	1,184	0	0	0	0
STF	0	0	3	120	2	41	4	121	39	207,390	3	4,695
OTH	1	25	1	400	0	0	1	213	0	0	0	0
Totals	60	60,797T	59	83,286T	45	22,651T	43	19,159T	52	240,003T	7	4,824T

- Six explosions at the pier had an outflow of 14,417 long tons out of a total of 19,159 long tons spilled;
- At sea, the 39 structural failures accounted for 207,390 long tons of outflow or 86.4 percent of the "at sea" total.

Analysis by Registry

Table 12 shows for tankers greater than 10,000 dwt, tanker casualties and outflows normalized to both representative number and deadweight for a given flag of registry. The non-dimensional numbers A/B, A/D, C/B, and C/D are similar to those described previously.

Table 11, in general, reaffirms the data analyzed in this manner by reference 4.

Table 12A. Distribution of the World Tanker Fleet Greater Than 10,000 DWT as a Function of Registry During the 1969-1970 Period[14]

Country of Registry	(B) Percent of World Tanker Fleet[15]	(D) Percent of World Tanker DWT Tonnage[16]
Liberia	21.09	23.42
Norway	11.50	13.84
United Kingdom	11.86	12.30
Japan	6.03	10.93
USA	10.30	6.50
Panama	4.27	3.78
France	3.14	3.71
Italy	3.49	3.22
USSR	4.93	2.90
Sweden	2.30	2.71
Greece	4.48	3.19
Netherlands	2.60	2.40
Others	14.01	11.10
	100.0	100.0

14 See footnote 8 on page

15 Based on 3,344 worldwide tankers over 10,000 DWT.

16 Based on 131,689,940 world tanker fleet tonnage over 10,000 DWT.

Table 12B. Distribution of the 203 Polluting Incidents and Outflows as a Function of the Country of Registry During the 1969-1970 Period

Country of Registry	(A) Percent of Total Casualties[17]	(C) Percent of Total Outflows[18]
Liberia	33.50	43.38
Norway	6.40	8.88
United Kingdom	15.76	16.27
Japan	2.96	0.24
USA	7.39	0.88
Panama	5.42	9.47
France	1.97	0.06
Italy	0.98	0.02
USSR	0.49	0.02
Sweden	1.48	1.42
Greece	13.30	9.49
Netherlands	1.48	2.73
Others	8.87	7.14
	100.0	100.0

17 Based on 203 incidents involving tankers greater than 10,000 DWT.
18 Based on total outflow of 419,781 long tons.

Table 12C. Non-Dimensional Analysis of 203 Tanker Casualties and Their Outflows as a Function of Tanker Registry During the 1969-1970 Period

Country of Registry	A/B	A/D	C/B	C/D
Liberia	1.59	1.43	2.06	1.85
Norway	0.56	0.46	0.77	0.64
United Kingdom	1.33	1.28	1.37	1.32
Japan	0.49	0.27	0.04	0.02
USA	0.72	1.14	0.09	0.14
Panama	1.27	1.43	2.22	2.51
France	0.63	0.53	0.02	0.016
Italy	0.28	0.30	0.006	0.006
USSR	0.10	0.17	0.004	0.007
Sweden	0.64	0.55	0.62	0.52
Greece	2.97	4.17	2.18	2.97
Netherlands	0.57	0.62	1.05	1.14
Others	0.63	0.80	0.51	0.64

Comparison with MP XIII/2(a)/9

Overall, it is difficult to make a point by point comparison with MP XIII/2(a)/9. The principal reasons for this are:

- MP XIII/2(a)/9 only considered incidents involving tankers of 7,000 DWT and larger whereas this study considers all tankers of 100 grt and larger;
- MP XIII/2(a)/9 only has total number for outflows in terms of the types of incidents whereas this study considers each incident on a frequency and magnitude scale. For example, Table 6.1 of reference 4 shows only the frequency of accidents as a function of tanker age with no direct correlation to the outflow magnitude. Postulations made on the basis of tanker casualty frequency only without recourse to outflow magnitude can be misleading; and
- MP XIII/2(a)/9 considers other factors such as cause of accident, weather conditions, time of day, etc. which this study does not contain within its data base.

There are, however, a number of points which deserve comment:

- As shown in Table 13, MP XIII/2(a)/9, does not include in its 1969-1970 data base, seven major incidents with a total outflow of 153,402 long tons. Inasmuch as the data base for this study does not include years prior to 1969, one cannot make a comparison to those years. One must, however, speculate as to their completeness.[19]

[19] It is realized that explosions have been specifically omitted in MP XIII/2(a)/9. They do nevertheless contribute to the total outflow.

Table 13. Some Major Incidents Which Occurred in 1969 and 1970 and Are Not Reported in MP XIII/2(a)/9

Vessel Name	Case Number	Type of Incident[20]	Outflow
ALBACRUZ	001	Structural failure - Broke up	20,400
ANASTASIA J L	003	" " "	18,500
CHRYSSI	013	" " "	31,216
GEZINA BROVIG	037	Mech. Breakdown-Aground-Broke up	16,350
PACOCEAN	080	Structural failure - Broke up	30,016
SILVER OCEAN	096	" " "	18,300
SOFIA P	097	" " "	18,620
Outflow Total			153,402 Tons

[20] All incidents involved loaded tankers.

. The deadweight analysis more or less agree in terms of incident frequency except for the very large tankers. This is in most part due to the omission of tanker explosions in MP XIII/2(a)/9. If this study likewise omitted these explosions the non-dimensional number, A/B, for tankers greater than 80,000 dwt would be 1.06; or in other words, the accident frequency for large tankers is in direct proportion to their number. In fact if one looks at their oil outflows as a function of the number of tankers in the greater than 80,000 dwt range, this non-dimensional number, C/B, is 0.49 when all explosions are discounted.

. The analyses with respect to the tanker's age both agree in that those tankers constructed between 1946 and 1955 have the poorest casualty history.

. Both studies concur in that tanker in ballast have fewer casualties than loaded tankers.

. It is unclear how the average annual outflow of 50,000 tons for tankers greater than 7,000 dwt cited in MP XIII/2(a)/9 was extrapolated to an annual outflow of 150,000 tons for all tankers. This value appears low and is at least in part attributable to omissions of major incidents as demonstrated by Table 13.

. Table 14 is a comparative analysis of frequency and magnitude as a function of the type of casualty.

This table shows two important points:

1. In both studies, the ratio of outflows from groundings to collisions is on the order of 4 to 1; and

Table 14. Frequency and Outflow for Various Types of Casualties

	This Study[21]		MP XIII/2(a)/9	
	Frequency	Magnitude	Frequency	Magnitude
Collisions	41%	9%	34%	16%
Groundings	34%	34%	53%	64%
Structural Failures	25%	57%	13%	20%
	100	100	100	100

21 For comparative purposes, only collisions, groundings and structural failures are tabulated here.

2. The absence of the major structural failures from MP XIII/2(a)/9 has a distinct effect upon absolute values of the outflow magnitudes.

Closure

The most significant type of tanker casualty in causing oil pollution is structural failures. Ten major structural failures (4 percent of the total number of incidents) accounted for 206,278 tons of outflow (48 percent of the total outflow). They all occurred in the fully loaded condition and resulted in the total loss of the tanker.

Groundings are the next major contributor to oil outflow. In 1969 and 1970 they accounted for 28 percent of all tanker casualty pollution. In terms of outflow from all polluting incidents, groundings are four times more significant than collisions.

Analysis of tanker pollution data in terms of frequency, without data on amounts of outflow, is not a true measure. In terms of total incidents, collisions are the largest single type of casualty. However, collisions contribute only eight percent of the total outflow and are of less magnitude than structural failures and groundings.

Rammings account for approximately nine percent of the total incidents but resulted in only one percent of the total pollution.

Explosions which are extremely significant because of their cost and danger to life contribute 7.9 percent of the total outflow. This is of course the result of most explosions occurring while in the ballast condition.

Nearly 56 percent of the total oil outflow occurs "at sea"; i.e., more than 50 miles from any shoreline. Fourteen percent is spilled in the coastal zone and the remaining 29 percent is spilled in the "local zone"; i.e., at entranceways, within harbors, and at piers.

In terms of localized pollution, grounding are by far the most significant source of oil outflow accounting for some 71 percent. Structural failures account for 90 percent of the "at sea" pollution. They contribute very little elsewhere.

There is no clear decision to state with respect to the effect of tanker size. In terms of frequency, the very large ships look poorest. As stated previously, however, this is due primarily to explosions. When oil outflow magnitudes are considered, then vessels less than 50,000 DWT display the poorest record. In terms of both frequency and magnitude it would appear that tankers in the 10,000 to 19,999 DWT range the worst history, i.e., all non-dimensional numbers, A/D, A/D, C/B and C/D are 1.39 or greater.

Tanker age only has an effect on structural failures. In short, those tankers built between 1946 and 1955 had a disproportionate amount of catastrophic structural failures.

The incidents involving the loss of the tanker have a significant effect upon the total outflow figure. They must be recognized and especially accounted for in any analysis.

In conclusion, this study shows the following important points:

. Accidental oil outflows from tankers is on the order of 215,000 long tons or 218,440 metric tons per year;

. Structural failures, groundings, and explosions involving the total loss of tankers have a distinct effect upon any analysis conducted. In this respect, tanker survivability must be considered;

. Groundings exceed collisions in terms of outflows by a factor of 4 to 1. This would tend to put an extreme accent on the need for bottom protection over side protection;

. Explosions on large tankers especially, and on all tankers in general, deserve some immediate reaction;

. Certain flags of registry appear to need an upgrading in their standards and maintenance requirements; and,

. There is no clear indication that tanker size has any relationship to casualty frequency and oil outflow other than in the case of explosions.

REFERENCES

1. M. P. Holdsworth, "Oil Pollution at Sea", paper presented to the Symposium on Environmental Pollution, University of Lancaster, 1971.

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3. J. D. Porricelli, V. F. Keith, and R. L. Storch, "Tankers and the Ecology", Trans. SNAME, Vol. 79, 1971.

4. "Study on Accidental Marine Pollution by Oil", report presented to IMCO, MP XIII/2(a)/9 by France, June 1972.

5. "Pollution and the Maritime Industry", ALCAN Shipping Service, Ltd., 1971.

6. Report submitted to IMCO DE Subcommittee by the International Chamber of Shipping, February 1971.

7. "Systems Study of Oil Spill Cleanup Procedures", Dillingham Environmental Co., February 1970.

8. "Report on Study I - Segregated Ballast Tanker", note by the United States of America to IMCO, June 1972.

APPENDIX I

266 TANKER POLLUTING INCIDENTS

WHICH OCCURED IN 1969-1970

KEY

Columns 1-3	Incident Number	
Columns 4-7	Date (Month-Year)	
Columns 8-13	Deadweight	
Columns 14-15	Year Built	
Column 16	Cargo Condition	L = Loaded
		B = Ballast
		O = Other than persistent oil
		U = Unknown
Columns 17-18	Geographical Location (See table 8)	
Column 19	Area P = Pier	
	H = Harbor	
	E = Entranceway	
	C = Coastal	
	S = Sea	
	U = Unknown	
Columns 20-23	Damage	Lost = Sunk
		S-HD = Heavy
		S-LD = Light
		S-UN = Unknown
Columns 24-26	Type Casualty	BKD = Breakdown
		CAP = Capsizing
		Col = Collision
		EXP = Explosion
		FRE = Fire

		GRD = Grounding
		RAM = Ramming
		STR = Structural Failure
Columns 27-32	Amount Outflow	
Columns 33-35	Method of Determining Outflow	REP = Report
		MIN = Reported as Minimal
		EST = Estimated
		CAL = Calculated

001	0170	020400	UN	L	02	S	LOST	STF	020400	REP
002	0269	019070	52	L	01	F	S-LD	GRD	000500	REP
003	1070	018500	52	L	02	S	LOST	STF	018500	REP
004	0969	018340	53	B	02	C	LOST	EXP	002500	EST
005	0570	019787	57	U	01	H	S-LD	COL	*000001	MIN
006	0370	018151	48	L	01	C	LOST	GRD	012000	REP
007	0369	026267	45	L	01	S	S-LD	STF	000010	REP
008	0769	074953	65	B	02	P	S-HD	FRE	000001	MIN
009	0569	074953	65	L	02	C	S-HD	COL	002000	REP
010	0170	019695	58	B	02	S	S-LD	STF	000001	MIN
011	0369	019000	*UN	B	03	E	S-HD	GRD	000001	MIN
012	0970	023256	45	L	13	P	S-LD	RAM	*000001	MIN
013	1270	031216	53	L	01	S	LOST	STF	031216	REP
014	0269	042788	57	U	UN	P	S-HD	RAM	000001	MIN
015	1069	018735	54	B	02	C	S-LD	COL	000001	MIN
016	1269	001681	44	L	01	P	S-HD	EXP	000500	REP
017	0270	026207	63	L	01	E	S-HD	GRD	000830	REP
018	0470	018840	54	L	02	F	S-LD	COL	000300	REP
019	0370	044270	60	L	01	C	S-HD	COL	001000	REP
020	0670	049209	63	L	12	E	LOST	GRD	049209	REP
021	0970	249952	69	L	12	C	S-HD	GRD	001200	REP
022	1269	027350	49	L	13	E	S-HD	COL	001900	EST
023	0770	040873	57	L	01	C	S-LD	GRD	000750	REP
024	0369	038344	60	B	01	C	S-LD	COL	*000001	MIN
025	0869	051306	63	U	13	P	S-LD	RAM	*000001	MIN
026	0569	084717	61	U	02	E	S-HD	GRD	000001	MIN
027	0169	039989	59	L	01	P	S-LD	STF	000001	MIN
028	0870	004431	67	L	02	H	S-LD	COL	000080	REP
029	0870	000850	63	L	02	E	S-HD	COL	000001	MIN
030	0870	038156	57	L	01	F	S-	GRD	001550	REP
031	0469	016400	55	U	02	C	S-HD	COL	*000001	MIN
032	0469	002500	67	L	50	C	S-LD	GRD	000400	REP
033	0570	020827	60	L	12	H	S-HD	COL	001470	EST
034	1069	030400	61	L	13	F	S-LD	COL	*000001	MIN
035	0170	020480	55	L	02	C	S-HD	COL	000102	CAL
036	1269	018560	53	B	07	E	S-HD	GRD	001200	REP
037	0270	016350	51	L	03	S	LOST	BKD	016350	REP
038	0469	000888	66	B	21	C	LOST	GRD	000050	EST
039	0869	025589	UN	L	02	C	S-HD	COL	000200	REP
040	0769	073829	67	L	01	S	S-LD	STF	005680	REP
041	0469	019715	59	L	02	C	S-HD	COL	000600	REP
042	0869	018927	54	U	UN	E	S-LD	COL	000001	MIN
043	0569	001404	16	B	02	C	S-HD	GRD	000001	MIN
044	1169	033804	55	L	01	P	S-LD	RAM	001000	REP
045	0369	019047	57	L	13	P	S-HD	FRE	000001	MIN
046	0169	018942	55	U	13	H	S-LD	COL	000001	MIN
047	0769	212010	69	B	02	H	S-LD	STF	000001	MIN
048	0269	019104	55	L	02	H	S-HD	GRD	009000	REP
049	1070	001324	65	L	21	C	LOST	EXP	001324	REP
050	0569	017026	50	B	12	C	S-LD	GRD	000001	MIN
051	1170	046765	59	B	11	C	S-HD	GRD	000001	MIN
052	1169	030006	49	L	01	S	LOST	STF	030006	REP

053	0770	018607	54	U	01	E	S-LD	GRD	000001	MIN
054	0669	099347	66	B	13	S	S-HD	EXP	000001	MIN
055	1269	219000	69	B	04	S	S-HD	EXP	000001	MIN
056	0970	034760	59	B	13	C	S-LD	GRD	000001	MIN
057	1070	000165	56	L	26	U	LOST	STF	000165	REP
058	0769	003400	67	B	02	S	S-HD	FRE	000001	MIN
059	0169	003185	66	B	02	C	S-LD	GRD	000001	MIN
060	1269	208460	69	B	12	S	S-HD	EXP	000001	MIN
061	0569	208445	68	B	02	F	S-LD	GRD	000001	MIN
062	0469	079576	58	L	02	F	S-HD	COL	000300	REP
063	1170	026107	50	L	50	C	S-HD	GRD	014000	REP
064	0870	000200*	62	B	21	C	LOST	CAP	000025	EST
065	0369	000500	32	L	01	P	S-HD	FRE	000300	REP
066	0270	025596	55	U	02	H	S-HD	RAM	001600	EST
067	0769	073146	64	B	12	P	S-LD	RAM	000001	MIN
068	0369	054345	62	L	01	F	S-UN	GRD	002400	REP
069	0470	001955	56	L	01	H	S-LD	GRD	000017	REP
070	0870	000600*	58	L	21	E	LOST	COL	000600	REP
071	0170	018280	57	L	02	E	S-HD	GRD	000850	REP
072	0370	060240	65	L	26	E	S-HD	GRD	006000	REP
073	0769	021313	53	L	04	F	S-HD	COL	000570	REP
074	1269	041636	49	B	03	C	S-LD	GRD	000001	MIN
075	0170	030005	49	L	01	S	S-LD	STF	000100	REP
076	1069	019995	55	L	07	H	S-HD	GRD	001700	REP
077	0370	003100	67	L	02	F	S-HD	COL	000050	REP
078	0870	000854	56	L	UN	P	LOST	FRE	000854	REP
079	1070	077648	66	L	02	C	S-HD	COL	006000	REP
080	1169	030016	49	L	23	S	LOST	STF	030016	REP
081	0770	017529	53	L	21	C	S-LD	COL*	000001	MIN
082	0569	016254	64	L	UN	F	S-LD	GRD	000200	REP
083	0270	013700	51	L	13	P	LOST	EXP	013700	REP
084	1269	038654	57	B	02	C	S-LD	GRD	000001	MIN
085	0570	050380	65	L	02	E	S-HD	GRD	013000	REP
086	0769	011570	61	U	UN	H	S-LD	RAM*	000001	MIN
087	1269	001251	20	L	01	P	LOST	FRE	001000	REP
088	0669	003925	45	L	01	H	S-LD	RAM	000100	REP
089	1270	017310	51	L	UN	S	LOST	STF	017310	REP
090	0769	049289	62	L	01	H	S-LD	RAM	001700	REP
091	0670	018370	54	B	02	C	S-LD	COL*	000001	MIN
092	1069	097950	66	B	13	S	LOST	EXP	005800	EST
093	0669	001600*	UN	P	21	C	S-LD	COL	000001	MIN
094	0869	021074	57	L	13	C	S-LD	COL	000800	REP
095	0769	100500	68	B	02	C	LOST	COL	007500	EST
096	0470	018300	50	L	11	S	LOST	STF	018300	REP
097	0170	018620	54	L	21	S	LOST	STF	018620	REP
098	0969	033019	57	B	UN	U	S-LD	GRD	000001	MIN
099	0770	000250*	57	L	21	C	LOST	COL	000250	REP
100	0769	089529	68	B	13	S	S-LD	STF	000001	MIN
101	1270	047193	61	B	01	H	S-LD	COL	000001	MIN
102	1270	043149	59	L	01	H	S-LD	COL	001800	REP

103	0969	100827	68	L	02	H	S-LD	GRD	000400	REP
104	1170	072141	65	B	21	P	S-HD	EXP	000001	MIN
105	0769	019899	44	L	07	H	S-LD	COL	001000	REP
106	0970	050230	63	B	UN	U	LOST	STF	004490	EST
107	0669	001172	63	L	02	C	S-HD	COL	*000001	MIN
108	1070	018050	56	B	13	U	S-HD	EXP	000001	MIN
109	0169	000500*	57	L	21	C	LOST	GRD	000500	REP
110	0569	033749	60	L	03	H	S-UN	GRD	000001	MIN
111	0569	020938	58	B	13	E	S-LD	GRD	000001	MIN
112	0369	027105	49	L	22	C	S-HD	GRD	001350	EST
113	0269	033611	57	B	21	S	S-HD	EXP	000001	MIN
114	0369	069696	57	L	02	H	S-LD	GRD	000001	MIN
115	1269	206000	69	B	04	S	LOST	EXP	010000	EST
116	0270	021208	61	L	50	C	S-HD	GRD	000700	REP
117	0870	018255	56	L	21	C	S-HD	GRD	003500	REP
118	0970	001335	69	L	02	P	S-LD	RAM	000018	CAL
119	1170	035925	57	L	03	E	S-LD	STF	000040	CAL
120	0969	019050	52	L	26	E	S-LD	STF	000040	CAL
121	0770	017618	54	U	13	H	S-LD	COL	000102	CAL
122	0870	016400	50	L	12	C	S-HD	BKD	000025	CAL
123	0769	029659	53	L	12	C	S-HD	GRD	000090	CAL
124	0370	087688	68	L	13	S	S-LD	STF	000040	CAL
125	0669	024200	51	L	02	S	S-LD	STF	000040	CAL
126	1169	021106	53	L	02	P	S-LD	FRE	000076	CAL
127	0869	015009	59	L	01	P	S-LD	RAM	000018	CAL
128	1269	029402	54	L	UN	S	S-HD	STF	000040	CAL
129	1269	085378	67	U	UN	U	S-LD	STF	000040	CAL
130	0470	018600	53	L	26	P	S-LD	COL	000102	CAL
131	0970	216821	70	L	12	C	S-HD	COL	002000	EST
132	1169	021100	57	L	01	S	S-LD	STF	000040	CAL
133	0169	000775	UN	L	02	E	S-HD	COL	000102	CAL
134	0669	001087	65	L	02	E	S-LD	GRD	000090	CAL
135	0869	016182	55	L	03	P	S-LD	RAM	000018	CAL
136	1270	111423	65	L	02	S	S-LD	COL	000102	CAL
137	0270	016808	54	U	50	C	S-HD	COL	000102	CAL
138	0769	053074	63	L	04	P	S-HD	CAP	000213	CAL
139	0869	054611	63	U	02	P	S-LD	COL	000102	CAL
140	0369	019340	53	L	06	P	S-LD	RAM	000018	CAL
141	0670	005133	44	B	05	H	LOST	COL	000478	EST
142	0269	018050	54	L	50	S	S-HD	STF	000040	CAL
143	0769	018350	53	L	03	E	S-LD	GRD	000090	CAL
144	0769	009301	49	L	03	E	S-LD	GRD	000090	CAL
145	0870	074985	64	L	02	P	S-LD	FRE	000076	CAL
146	0769	022899	58	U	UN	E	S-LD	COL	000102	CAL
147	0569	031216	53	L	13	E	S-HD	GRD	000090	CAL
148	0770	002300	61	U	21	C	S-HD	COL	000102	CAL
149	0769	060236	64	L	06	S	S-LD	STF	000040	CAL
150	0669	011984	59	U	13	P	S-LD	RAM	000018	CAL
151	0469	018350	52	U	50	E	S-HD	RAM	000018	CAL
152	1270	000838	63	O	02	H	LOST	COL	000066	REP
153	0269	001500*	UN	O	02	E	S-HD	COL	000102	CAL
154	0170	028205	58	L	23	E	S-HD	GRD	000090	CAL

155	1269	028205	58	U	13	S	S-HD	STF	000040	CAL
156	0769	000793	58	L	02	P	S-LD	COL	000102	CAL
157	0569	019073	58	L	01	P	S-LD	COL	000102	CAL
158	1269	069525	66	U	UN	S	S-HD	STF	000040	CAL
159	0669	027240	53	L	22	E	S-LD	COL	000102	CAL
160	0769	001015	44	U	UN	E	S-LD	COL	000102	CAL
161	0970	004030	64	L	02	E	S-LD	GRD	000090	CAL
162	1170	004431	67	L	02	P	S-LD	FRE	000076	CAL
163	1169	016485	52	L	02	F	S-LD	RAM	000018	CAL
164	0970	020328	58	L	02	C	S-HD	COL	000102	CAL
165	0369	020765	44	L	01	H	S-LD	COL	000102	CAL
166	0169	001223	59	L	02	E	S-HD	COL	000102	CAL
167	0669	001800	62	L	21	H	S-LD	COL	000102	CAL
168	0669	018560	53	L	01	H	S-HD	GRD	000001	MIN
169	0669	091823	58	L	21	H	S-LD	GRD	000090	CAL
170	0869	058549	63	U	02	P	S-LD	COL	000102	CAL
171	1069	034930	58	L	23	P	S-LD	RAM	000018	CAL
172	1170	072052	63	L	21	U	S-HD	BKD	000025	CAL
173	0569	017165	45	L	UN	P	S-LD	STF	000040	CAL
174	0469	020489	53	L	02	P	S-LD	RAM	000018	CAL
175	0669	000778	56	L	02	F	S-LD	FRE	000076	CAL
176	0270	024483	43	U	01	H	S-HD	RAM	000018	CAL
177	0970	025200	70	L	02	H	S-LD	GRD	000090	CAL
178	1270	002000*	43	L	14	H	S-LD	GRD	000090	CAL
179	0270	019624	56	L	50	E	S-HD	GRD	000090	CAL
180	1070	013923	56	L	02	C	S-LD	GRD	000090	CAL
181	0569	001100	65	O	02	E	S-LD	COL	000102	CAL
182	0569	001344	62	U	21	S	S-HD	STF	000040	CAL
183	0969	001200*	UN	U	UN	F	S-HD	COL	000102	CAL
184	0669	001050	44	U	50	C	S-LD	COL	000102	CAL
185	0470	001503	48	U	50	C	S-LD	GRD	000090	CAL
186	0969	020560	60	O	21	E	S-LD	GRD	000090	CAL
187	0869	056023	64	U	02	F	S-LD	GRD	000090	CAL
188	0969	066783	64	L	01	S	S-LD	STF	000040	CAL
189	0669	041040	56	U	50	C	S-LD	GRD	000090	CAL
190	0770	019825	59	U	UN	S	S-LD	STF	000040	CAL
191	0669	007500*	54	L	02	H	S-LD	RAM	000018	CAL
192	0170	033757	58	L	21	S	S-LD	STF	000040	CAL
193	0869	020480	59	L	02	P	S-LD	STF	000040	CAL
194	0769	015000	54	O	50	S	S-HD	FRE	000076	CAL
195	1069	020203	62	U	UN	H	S-LD	COL	000102	CAL
196	0569	001150	65	L	21	P	S-HD	FRE	000076	CAL
197	0270	011119	69	U	50	C	S-LD	COL	000102	CAL
198	0869	025000*	UN	U	13	S	S-LD	STF	000040	CAL
199	0769	017440	53	L	02	H	S-LD	GRD	000090	CAL
200	1170	206937	68	L	02	P	S-HD	FRE	000076	CAL
201	0869	018581	58	L	09	P	S-LD	RAM	000018	CAL
202	0269	000400*	69	O	21	E	LOST	CAP	000400	RPT
203	1069	019807	45	U	22	P	S-LD	RAM	000018	CAL
204	0569	015960	52	L	04	S	S-LD	STF	000040	CAL
205	0769	065964	66	U	21	H	S-LD	COL	000102	CAL
206	0569	043781	58	L	UN	S	S-LD	STF	000040	CAL
207	0269	000516	64	U	21	C	S-HD	COL	000102	CAL

208	1269	016230	52	[illegible]	04	S	LOST	STF	[illegible]	[illegible]
209	0469	019180	60	L	03	P	T-HD	EXP	000072	CAL
210	0469	000400	37	U	01	E	S-HD	COL	000102	CAL
211	0869	018361	60	L	UN	H	S-LD	COL	000102	CAL
212	1269	162029	69	L	21	C	S-LD	COL	000102	CAL
213	0770	001000*	59	L	21	C	S-LD	COL	000102	CAL
214	0169	065573	65	U	UN	S	S-LD	STF	000040	CAL
215	0470	018166	59	L	13	S	S-LD	STF	000040	CAL
216	0269	019800	53	L	UN	S	S-HD	STF	000040	CAL
217	0470	216490	69	B	02	P	S-LD	RAM	000018	CAL
218	0669	216508	69	L	02	H	S-LD	GRD	000090	CAL
219	0769	021313	53	L	03	E	S-HD	GRD	000090	CAL
220	0669	030674	53	L	13	H	S-LD	GRD	000090	CAL
221	0769	030521	54	U	02	C	S-HD	COL	000102	CAL
222	0370	031750	55	U	03	S	S-HD	STF	000040	CAL
223	1070	075912	60	U	13	E	S-LD	GRD	000090	CAL
224	0769	000300*	61	L	02	C	S-HD	FRE	000076	CAL
225	0470	000800*	UN	L	02	H	S-LD	COL	000102	CAL
226	0869	061645	65	U	UN	F	S-LD	COL	000102	CAL
227	0769	029680	51	U	01	H	S-LD	GRD	000090	CAL
228	1270	017000	54	L	02	E	S-LD	GRD	000090	CAL
229	0870	001385	42	L	01	P	S-HD	EXP	000072	CAL
230	0969	033854	60	L	07	H	S-LD	STF	000040	CAL
231	0970	001100	UN	L	50	P	S-HD	EXP	000072	CAL
232	0170	017310	51	L	02	F	S-LD	STF	000040	CAL
233	1069	001585	53	L	50	H	S-HD	FRE	000076	CAL
234	1269	048920	65	L	02	H	S-HD	GRD	000090	CAL
235	0869	018970	54	U	50	S	S-HD	COL	000102	CAL
236	0169	002000*	UN	L	02	H	S-LD	COL	000102	CAL
237	0669	063442	65	U	02	C	S-LD	COL	000102	CAL
238	0469	019760	60	U	50	H	LOST	FRE	001250	EST
239	0770	000300*	61	U	21	C	S-LD	COL	000102	CAL
240	0869	020035	52	L	UN	C	S-LD	GRD	000090	CAL
241	0769	058100	64	L	06	S	S-LD	STF	000040	CAL
242	1070	000600*	UN	U	21	F	LOST	COL	000500	RPT
243	0369	051030	60	L	02	S	S-HD	FRE	000076	CAL
244	0169	024350	51	U	02	C	S-HD	GRD	000090	CAL
245	0270	016950	53	O	02	S	S-HD	STF	000040	CAL
246	0769	051874	56	L	12	E	S-HD	GRD	000090	CAL
247	0469	012271	53	L	08	P	S-LD	STF	000040	CAL
248	1270	017560	70	U	07	E	S-LD	COL	000102	CAL
249	0669	020700	60	L	22	F	S-LD	COL	000102	CAL
250	0469	000526	68	O	02	E	S-HD	COL	000102	CAL
251	0169	000575	35	L	02	F	S-LD	GRD	000090	CAL
252	0769	018700	52	U	04	S	S-LD	STF	000040	CAL
253	0370	025930	43	U	03	S	S-LD	COL	000102	CAL
254	0769	019924	44	L	07	S	S-LD	STF	000040	CAL
255	0269	049722	53	U	UN	S	S-HD	STF	000040	CAL
256	0769	000745	51	O	02	C	S-HD	COL	000102	CAL
257	0170	041711	57	L	UN	H	S-LD	COL	000102	CAL
258	0769	028735	57	U	UN	U	S-LD	COL	000102	CAL
259	1270	025136	68	L	07	P	S-LD	COL	000102	CAL
260	0270	000450	58	L	02	H	S-LD	COL	000102	CAL

261	0969	008753	67	L	07	P	S-LD	FRE	000076	CAL
262	0770	018796	58	L	UN	S	S-LD	STF	000040	CAL
263	0569	018796	58	L	50	C	S-LD	GRD	000090	CAL
264	0669	001630	63	B	02	E	S-HD	COL	000102	CAL
265	0770	016520	55	U	12	C	S-HD	FRE	000076	CAL
266	1269	004041	50	L	08	H	S-LD	GRD	000090	CAL